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Orbit Determination and Ephemeris Computation

Digital Computer Program

by

Karlis Minka, Jacques Fein and Bruce E. Clemenz

Martin Company
Baltimore, Maryland 21203

CONTRACT NO. AF19(628)-4167

Scientific Report No. 2

May 1966

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for

Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
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ABSTRACT

This program is based on the analytical work contained in Report AFCRL 65-579 (Martin Report ER 13950, Ref. 1). In addition, some analytical methods not covered in the above report are presented in the appendix of this report.

The operating modes, general features and accuracy of the program are discussed. Operating instructions and input/output descriptions and definitions are provided. All symbols used in the program are listed and defined. Flow charts, descriptions and explanations of the program and subroutines are also included.

The program is written in Fortran IV and machine language (MAP). Double precision is used extensively.

FOREWORD

This computer program is the result of research which was performed for the Data Analysis Branch (CRMXA), Technical Services Division at AFCRL, USAF, L. G. Hanscom Field, Bedford, Massachusetts. The contractor's report number is ER 14226.

CONTENTS

I. INTRODUCTION

Orbit determination from satellite observations is, essentially, a process in which a theoretical orbit is fitted through the observations in a manner which minimizes some error function. The theoretical orbit is represented by the mathematical model, and the best fit, in the present program, is defined as one which minimizes the variance. The analytical foundations of the Minimum Variance Method employed in this program are presented in Ref. 1, which also includes the details of the mathematical model of the dynamical system. The present report deals with the computer program itself.

The program consists of two main parts: orbit estimation or filtering routine and ephemeris computation routine. The analytical treatment of the filtering routine is reported in Ref. 1, which includes some of the equations utilized in the ephemeris computation. The specific methods used in the ephemeris computation are presented in the appendix of this report, which also includes the development of additional equations used in the filtering routine, but not reported in Ref. 1. It must be pointed out that although the filtering and the ephemeris routines are two separate subprograms, they are interconnected with extensive logic, which enables the program to perform both operations simultaneously when required. This assures greater accuracy of the estimated orbit and saves considerable computer time.

The accuracy of the estimated orbit is dependent on three main factors: the observations, the filtering process, and the mathematical model of the dynamical system. The accuracy and frequency of the observations are, of course, outside the control of the program but are, nevertheless, some of the most important factors. One of the most difficult problems is the screening of illegitimate observations when the interval between observations is large and/or when the total number of observations is small. This is because, under the circumstances, there is no real basis for a rejection criterion. To cope with such problems, a rather elaborate rejection technique was developed which is outlined in Ref. 1 and further discussed in Sections C and D of the Appendix.

A special program was developed to test the filtering method. It was established that for normally distributed observation errors, the filtering process converges to the true values of the orbital elements within the numerical accuracy of the computer by processing about 50 to 100 observations. The convergence, however, is asymptotic, and gains in accuracy are small in the latter phase of filtering.

The third factor which affects the accuracy is the mathematical model of the dynamical system. In the present program, it includes

Jacchia's 1964 model atmosphere and six zonal harmonics. The equations for additional harmonics and solar and lunar perturbations have been developed in Ref. 1 and can be easily included in the present program. However, it was considered that a significant increase in computing time resulting from their inclusion is not justified under the present circumstances. The higher order perturbations, however, are included in special purpose programs (Ref. 3).

II. PROGRAM DESCRIPTION

A. MODES OF OPERATION

The program is designed to perform two main functions: Obtain a best estimate of the orbit and compute the ephemeris. Thus, the program could be separated into two parts. In actuality, the two parts are interconnected in the sense that the ephemeris is computed concurrently with the filtering whenever the two time periods coincide and the filtering is performed in the forward direction for the last time.

The program can be operated in three modes. The first is a single filtering mode. This mode will, normally, be used when the initial estimate of the orbit and the system observation errors are well known. This can happen in restarting the filtering with orbital elements obtained from a previous filtering and with observations for a subsequent time period. If the ephemeris is required from a time previous to the input values, the program will integrate backward to the first required ephemeris time, then integrate forward while computing ephemeris until the first observation is encountered. From this point, filtering and ephemeris computation is done concurrently until the last observation is encountered. If the ephemeris is required past the last observation, there is an option for smoothing (see Section II-D) wherefrom the integration and ephemeris computation proceeds to the final time. It is obvious that in order to utilize this mode of operation, the initial estimate of the orbit must be good if the ephemeris is required for periods where the filtering has not improved the estimate to the desired degree. The specification of the time period for the ephemeris computation is arbitrary but, of course, must be kept within reason. A schematic illustration of the mode is shown in Fig. 1.

It must be pointed out that the initial values of the orbital elements can be given for any time, but for practical reasons must be close to the time of the first observation or the first ephemeris time to avoid excessive integration.

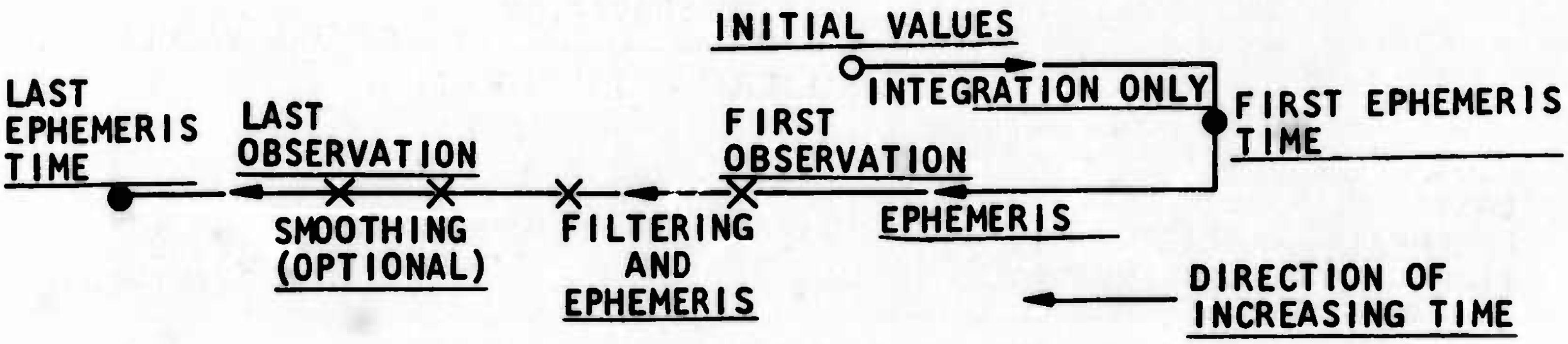

FIGURE 1. FIRST MODE OF OPERATION

The second mode of operation involves triple filtering and is used whenever the standard deviations of the observations for the system are not known and/or the initial estimate of the orbit is not known with sufficient accuracy.

A number of observation sets (up to 200 cards) can be specified which will be filtered three times. This is done in order to estimate the standard deviations of the observations for the system and to obtain a good estimate of the orbit in case the ephemeris output is required in a region close to the first observations. The process is started with the initial estimates of the orbital elements and system observation errors by filtering forward the specified number of observation cards (normally 20 to 40 or one to two days of observations). At the end of the first filtering, an improved estimate of the system standard deviations and the rejection criterion (see Appendix, Sections C and D) are computed, and the filtering is continued backward. The process is repeated during and after the backward filtering. If ephemeris is required prior to the first observation, the orbit is integrated backward to the first ephemeris time and the ephemeris computed while integrating forward. The further process is similar to the corresponding part of the first operating mode. An illustration of the mode is shown in Fig. 2.

The rejection process is not shown in the diagram, but is done whenever filtering is performed. It was established that no noticeable gains in accuracy were achieved by filtering more than three times. It must be pointed out that the rejection criterion is continuously being tightened during the filtering and not just at the end of each filtering process as in the case with the Least Squares Method in a multiple filtering mode.

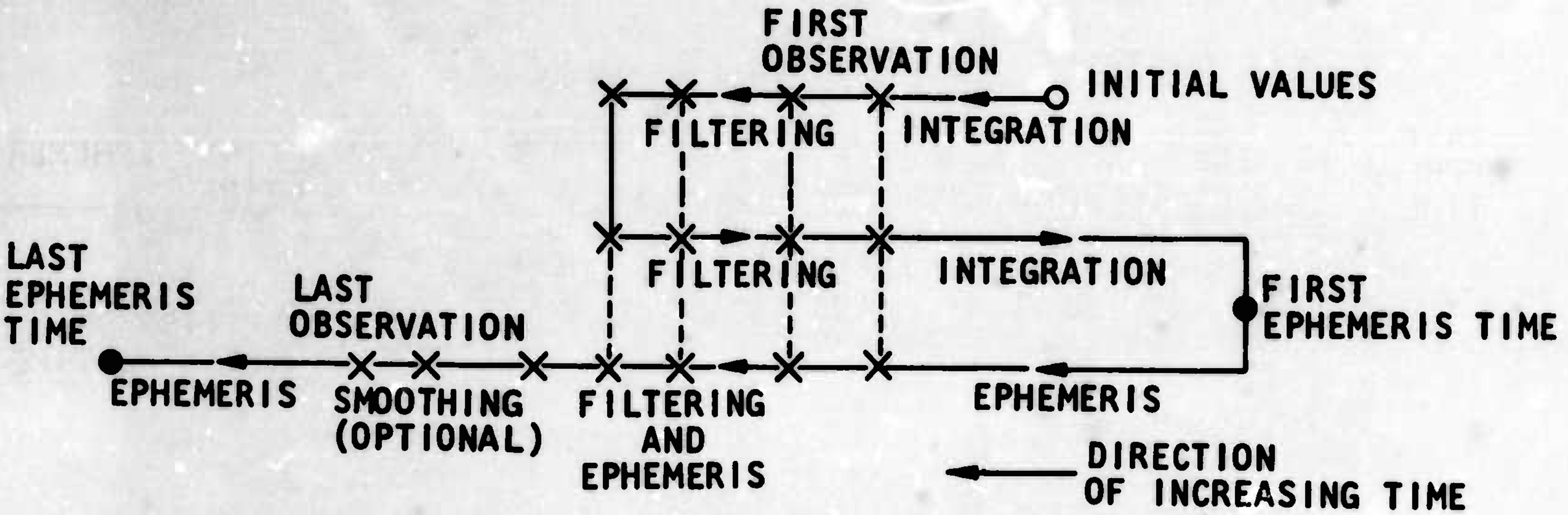

FIGURE 2. SECOND MODE OF OPERATION

The third mode of operation does not involve filtering and is used only for predicting the ephemeris (including observations) from given initial conditions. Thus, it can be used in preflight orbit analysis.

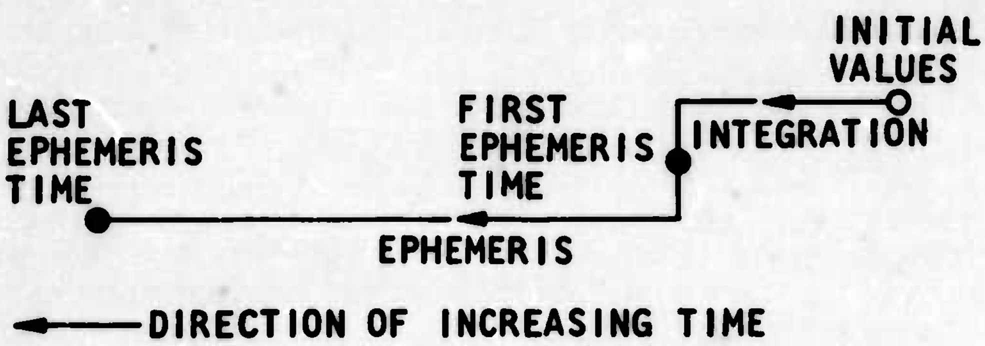

FIGURE 3. THIRD MODE OF OPERATION

As in the first two modes, the first and last ephemeris times are arbitrary in relation to the time of the initial values.

B. OBSERVATION ERRORS

To fully utilize the capabilities of the Minimum Variance Method, it is necessary to know the standard deviations of the observations, which are used to obtain the weighting matrix. In defining the standard deviations, however, two factors must be considered. First, the mathematical model of the actual dynamical system is not perfect. Therefore, in fitting the theoretical orbit, the errors in the mathematical model will be accommodated as observation errors. Secondly, there are unknown bias errors in individual observation systems (station locations, etc.). The theory of the Minimum Variance Method is based on a normal or Gaussian error distribution. The determination of the bias errors simultaneously with the orbital elements, although possible, is not practical for a general type orbit determination program, because the error functions and bias constants will have to be defined separately for each individual station. Therefore, the approach taken in the present program is based on the standard deviations for the entire system instead of the individual stations. Since, in all probability, the observation biases (including locations) for all observing stations will not be biased in the same direction, the system bias will become more negligible as the number of stations increases. The standard deviations for the system now will include the biases of the individual stations, but they can be considered random for the system. The system standard deviations (which include the bias errors) can be estimated by successive approximations in a multiple filtering process. This is done in the present program when operating in the second mode or triple filtering.

Initally, an estimate is made of the system observation errors. This estimate is used in the first forward filtering. In addition, a number of sigmas are inputted which are used for the rejection criterion (Appendix, Section D) during the first filtering. Since the orbit and the system standard deviations are not known accurately, the number of sigmas for the first filtering is usually large (50 to 100). Thus only grossly inaccurate observations will be rejected during the first filtering. At the end of the first filtering, better estimates of the system standard deviations are computed based on the filtering results. Also the number of sigmas for the rejection criterion is now computed. This number will usually be three, unless the initial estimates of the system standard deviations have been considerably underestimated, in which case the number of sigmas will be larger to avoid rejection of legitimate observations. These estimates are used for the second or backward filtering, at the end of which new and improved estimates of these quantities are obtained, which now are used for the third or forward filtering phase.

During the three filterings, the criterion for rejection of observations is continuously tightened as the orbit becomes known with higher

accuracy. However, the improvement in accuracy of the orbit becomes small during the latter phases of filtering as it is strongly dependent on the restraining accuracy of the observations. Thus, the criterion for rejection is essentially constant during the last filtering phase.

C. ITERATION

Unfortunately, in practice, there are many cases when observations are infrequent and may involve intervals of several days. If the filtering has not progressed at time t_k to the point where the orbit is known with sufficient accuracy, the deviation of the estimated orbit from an observation at time t_{k+1} after a long interval may be large. Assuming a legitimate error in the observation at t_{k+1}, this may, normally, indicate a perfectly legitimate error in the estimate of the orbit at time t_k. Since the filtering method is based on linear assumptions, this large discrepancy between the observation and the estimated orbit will certainly violate the linearity and consequently affect the computed corrections and thus degrade the accuracy of the estimated orbit. On the other hand, because of the nature of orbits, the large discrepancy at time t_{k+1} is caused by a relatively small error in the orbital elements at time t_k. This error at t_k is, normally, well within the one sigma accuracy.

On the basis of these considerations, a method was developed to cope with this problem. After computing the corrections of the position and velocity vector for a new observation at time t_{k+1} by use of the weighting matrix, the corrections are tested against a criterion. If they exceed the allowable limits, an iterative process is begun whereby the corrections at t_{k+1} are transferred to t_k by use of the state transition matrix

$$x(t_k) = \Phi\,(t_k, t_{k+1})\, x\,(t_{k+1}) \tag{1}$$

or its inverse

$$x(t_k) = \Phi^{-1}\,(t_{k+1}, t_k)\, x\,(t_{k+1}) \tag{2}$$

whichever is more convenient. The corrections to the orbit are made at t_k and the orbit integrated again to t_{k+1}. If the orbital process would, indeed, be linear, the iterated orbit at t_{k+1} would correspond

to the linearly corrected orbit. Since it is not, the iterated orbit will be different. The process is convergent and is repeated until the corrections at t_{k+1} become tolerable, which usually occurs in less than three iterations. The method has proved itself to be very valuable in difficult cases.

D. SMOOTHING

The estimated orbit is not continuous as determined by the Minimum Variance Method in the form of discrete position and velocity vectors at the observation times. The discontinuities are represented by the corrections. However, by using the filtering methods outlined in Section II-A, the discontinuities are, normally, negligible during the ephemeris computation phase. Therefore, smoothing for this purpose is not considered necessary and thus considerable savings in computing time can be achieved. However, in predicting the orbit for a future period of time, every available means should be utilized to improve the final position and velocity vector, since it becomes the sole source of information for the future orbit. In the present program, smoothing is employed for this purpose. The final orbit is smoothed through the last six points which are at least 10 min. apart and for which the total time span does not exceed 1. 5 days. These values were chosen for practical and numerical reasons. The theory is developed in Section B of the Appendix. The prediction for a time previous to the first observation is not based on a smoothed value and, therefore, will be somewhat less accurate depending on the accuracy of the estimate.

E. NUMERICAL METHODS

In dealing with matrices of even moderate order (the largest matrix encountered in the present program is 7 x 7) and continuously processing a large number of data, it is seldom that certain numerical problems do not arise. The main difficulties in this type of program are, usually, connected with matrix inversion and the degradation of the numerical values due to the accumulation of round-off errors.

The analytical and numerical methods used in the present program virtually eliminate any difficulties in matrix inversion (see Ref. 1, Section V-D). This has been borne out by extensive experience, which has shown no evidence of such problems.

The second problem, connected with the degradation of the numerical values, however, is always present in dealing with a large amount of data and extensive matrix operations. Therefore, it has been necessary to introduce certain numerical manipulations to assure a continuous operation of the program.

One of the problems concerns the covariance matrix. Theoretically, the covariance matrix should always be symmetrical and the diagonal elements should always be positive. In practice, however, the covariance matrix becomes unsymmetrical, and occasionally a diagonal element may assume a negative value as a result of round-off error accumulation in extensive matrix operations.

To cope with the symmetry problem, the program employs a process whereby the covariance matrix is symmetrized by equalizing one side of the diagonal to the other side after every major operation. This is faster than averaging and the error introduced is negligible, since only the last one or two places of an element are normally unsymmetrized in a particular operation, as borne out by experience.

The negative diagonal elements can occur in the process of transforming the covariance matrix over a long time period. This implies extensive correlation of the elements. The remedy in such case is to strip the matrix of the covariance elements and transform only the diagonal matrix. This is done in the program. This case is more likely to occur at the beginning of the filtering process when the initial estimate of the orbit is rather poor.

Another case where negative diagonal elements may appear in the covariance matrix is in the updating process. In particular, this is more likely to occur in cases where accurate measurements are introduced at a point where the orbit is relatively poorly known. In this case, updating involves the substruction of two matrices of equal magnitude. This problem can be coped with by assuming the previous updated value for the particular element, or by some other reasonable method.

It must always be remembered that, in practice, the covariance matrix is not an array of absolute numbers and, therefore, can be dealt with accordingly. The occasional occurrence of the negative diagonal elements in covariance matrix operations itself proves this point since theoretically it should not happen.

The numerical problems discussed above can be alleviated by carrying more digits, in other words, using double precision in the matrix operations. This is done in the present program wherever necessary.

F. COMPUTATION OF EPHEMERIS

The second function of the program is to compute the required ephemeris and related quantities. As mentioned before, the ephemeris is computed concurrently with the last forward filtering, when the two time periods coincide. In addition, it is computed outside the filtering

region whenever required. The initial and final times are input values, as is the computation interval.

In addition to the regular printout times, up to 20 odd printout times can be specified.

The quantities computed and printed out are: date and time, revolution number, position and velocity, Greenwich mean sidereal time, classical orbital elements, observations and their time rates for a specified number of stations. Six options are available for computing the desired quantities. For more detail, see Input and Output sections.

Output can be specified as regular printout, binary tape, and binary coded decimal (BCD) tape.

III. PROGRAM INPUT

A. NOTE ON THE INPUT

ALL VARIABLES ARE FLOATING POINT (REAL) NUMBERS UNLESS OTHERWISE SPECIFIED.FLOATING POINT NUMBERS ARE NUMBERS WITH A DECIMAL POINT. MOST OF THE VARIABLES WHICH ARE FLOATING POINT NUMBERS HAVE BEEN ALLOTTED 13 OR 15 COLUMNS. IF A FLOATING POINT NUMBER MUST BE WRITTEN IN ITS EXPONENTIAL FORM (E.G. ±.XXXXXXXXE±XX OR EQUIVALENTLY ±.XXXXXXXX±XX),THEN THE EXPONENT MUST BE RIGHT MOST ADJUSTED IN THE COLUMNS ALLOTTED.

FIXED POINT VARIABLES MUST BE RIGHT MOST ADJUSTED IN THE COLUMNS SPECIFIED.IF ON CARD 2, NOSAT =1, THEN 1 MUST BE PUNCHED IN COLUMN 5. IF NOSAT =12,THEN 1,2 MUST BE PUNCHED IN COLUMNS 4,5 RESPECTIVELY.

B. INPUT SYMBOLS

CARD	VARIABLE	DEFINITION	COLUMNS
1	TITLE	ANY DESCRIPTIVE TITLE	1-66
2	A) NOSAT	SATELLITE NUMBER.MUST AGREE WITH CORRESPONDING COLUMNS OF OBERVATION CARDS. (FIXED POINT)	1-5
	B) NMS	NUMBER OF STATIONS INPUT. 1≤NMS≤60 (FIXED POINT)	7-8
	C) NOH	=1,REJECT ANY OBSERVATION CARD WITH ELEVATION ANGLE LESS THAN ELEMIN OR GREATER THAN ELEMAX. =0,DO NOT REJECT ANY OBSERVATION CARD	11
	D) NAT	=1,CORRECT ELEVATION AND/OR RANGE AND/OR RANGE RATE FOR REFRACTION. =0,NO CORRECTION	14
	E) MERASE	=1,INPUT ZONAL HARMONICS(2-6),REARTH,F,OMU. =0,DO NOT INPUT ZONAL HARMONICS(2-6),REARTH,F,OMU. **** SEE CARDS 11 AND 12 ****	17
	F) KOHSPR	=1,PRINT OUT FILTERING OUTPUT =0,DO NOT PRINT OUT FILTERING OUTPUT	20
	G) KCOUNT	NUMBER OF OBSERVATION CARDS TO BE FILTERED MORE THAN ONCE. 0≤KCOUNT≤200 IF KCOUNT IS ZERO THE PROGRAM WILL FILTER ALL OBSERVATION CARDS ONLY ONCE. IF KCOUNT IS NOT EQUAL TO ZERO THE FIRST KCOUNT CARDS WILL BE FILTERED THRICE AND ANY REMAINING CARDS WILL BE FILTERED ONCE.	21-23
	H) ISMOOH	=1, APPLY A SMOOTHING TECHNIQUE. SMOOTHING WILL OCCUR ONLY IF THE EPHEMERIS TIME EXTENDS BEYOND THE TIME OF THE LAST OBSERVATION CARD =0, NO SMOOTHING	26
	I) NSTPRT	NUMBER OF STATIONS TO BE CONSIDERED DURING EPHEMERIS PRINTOUT. 0≤NSTPRT≤NMS IF NSTPRT EQUALS ZERO NO OBSERVATION DATA WILL BE COMPUTED. IF NSTPRT IS NOT ZERO, THE FIRST NSTPRT STATIONS INPUT(SEE CARD 3) WILL BE CONSIDERED FOR OBSERVATION DATA COMPUTATION. NOTE, IF KEYTAP EQUALS 0 OR -1, AND JTYPRT EQUAL 3,4 OR 5, THEN NSTPRT MUST NOT EQUAL ZERO. (KEYTAP AND JTYPRT ARE DEFINED ON CARD 13)	28-29

CARD	VARIABLE	DEFINITION	COLUMNS
	J) PASS	=1.0, SINGLE CORRECTION OF RANGE FOR REFRACTION. =2.0, DOUBLE CORRECTION OF RANGE FOR REFRACTION.	30-32
	K) TNEXOS	IF POSITIVE, NIGHT EXOSPHERIC TEMPERATURE (DEG K) IF NEGATIVE, 10.7 CM SOLAR FLUX. PROGRAM WILL SET IT POSITIVE AND CONVERT IT TO NIGHT EXOSPHERIC TEMPERATURE.	45-59
	L) IREVU	REVOLUTION NUMBER AT THE TIME OF THE INPUT ORBITAL ELEMENTS (FIXED POINT)	60-65
	M) TIMTOL	SYSTEM TIMING ERROR (SEC)	66-74
3	STATION DATA		
	A) NUMSTA(I)	STATION NUMBER. MUST AGREE WITH CORRESPONDING COLUMNS OF OBSERVATION CARDS (FIXED POINT)	2-5
	B) NSG(I)	=1, ELEVATION AND AZIMUTH ARE MEASURED WITH RESPECT TO GEOCENTRIC SYSTEM =2, ELEVATION AND AZIMUTH ARE MEASURED WITH RESPECT TO GEODETIC SYSTEM	8
	C) SLON(I)	STATION LONGITUDE (DEGREES) POSITIVE TO WEST FROM GREENWICH	9-23
	D) PHILAT(I)	STATION GEODETIC LATITUDE (DEGREES)	24-38
	E) ALT(I)	STATION ALTITUDE (METERS)	39-53

*** I=1,...,NMS. ALL STATIONS DEFINED ON THE OBSERVATION CARDS MUST BE REPRESENTED IN THIS SET.

CARD	VARIABLE	DEFINITION	COLUMNS
4	SATELLITE DATA		
	A) UMSAT	MASS (KG)	1-15
	B) SSAT	REFERENCE AREA (METERS SQUARE)	16-30
	C) CDRAG	DRAG COEFFICIENT	31-45

CARD	VARIABLE	DEFINITION	COLUMNS
5		DATE AND UNIVERSAL TIME OF THE INPUT ORBITAL ELEMENTS	
	A) MOHS(2)	YEAR,LAST 2 DIGITS OF 19XX (FIXED POINT)	2-3
	B) MOHS(3)	MONTH (FIXED POINT)	5-6
	C) MOHS(4)	DAY (FIXED POINT)	8-9
	D) ZDAT(1)	HOUR OF THE FORM XX.0	11-14
	E) ZDAT(2)	MINUTE OF THE FORM XX.0	16-19
	F) ZDAT(3)	SECOND OF THE FORM XX.XXX	21-26
6		ORBITAL ELEMENTS	
	A) AXSEMI	SEMI-MAJOR AXIS (KILOMETERS)	1-13
	B) ECCEN	ECCENTRICITY	14-26
	C) OINCL	INCLINATION (DEGREES)	27-39
	D) WASC	RIGHT ASCENCION OF ASCENDING NODE (DEGREES)	40-52
	E) WPERI	ARGUMENT OF PERIGEE (DEGREES)	53-65
	F) XMEAN	MEAN ANOMALY (DEGREES)	66-78
7		INITIAL ESTIMATE OF POSITION AND VELOCITY ERRORS	
	A) PMAT(1,1)	ESTIMATED ERROR IN X(0) COORDINATE (KM)	1-13
	B) PMAT(2,2)	ESTIMATED ERROR IN Y(0) COORDINATE (KM)	14-26
	C) PMAT(3,3)	ESTIMATED ERROR IN Z(0) COORDINATE (KM)	27-39
	D) PMAT(4,4)	ESTIMATED ERROR IN $\dot{X}(0)$ COORDINATE (KM/SEC)	40-52
	E) PMAT(5,5)	ESTIMATED ERROR IN $\dot{Y}(0)$ COORDINATE (KM/SEC)	53-65
	F) PMAT(6,6)	ESTIMATED ERROR IN $\dot{Z}(0)$ COORDINATE (KM/SEC)	66-78

CARD	VARIABLE	DEFINITION	COLUMNS
8	INITIAL ESTIMATE OF MEASUREMENT ERRORS (STANDARD DEVIATIONS)		
	A) QP(1)	ERROR IN DECLINATION (SECONDS OF ARC)	1-8
	B) QP(2)	ERROR IN RIGHT ASCENSION (SECONDS OF ARC)	9-16
	C) Q(1)	ERROR IN ELEVATION (SECONDS OF ARC)	17-24
	D) Q(2)	ERROR IN AZIMUTH (SECONDS OF ARC)	25-32
	E) Q(3)	ERROR IN RANGE (KM)	33-40
	F) Q(4)	ERROR IN RANGE RATE (KM/SEC)	41-48
	G) Q(5)	ERROR IN ELEVATION RATE (SECONDS OF ARC/SEC)	49-56
	H) Q(6)	ERROR IN AZIMUTH RATE (SECONDS OF ARC/SEC)	57-64
	I) Q(7)	ERROR IN RANGE ACCELERATION (KM/SEC^2)	65-72
9	CT(1-9)	NUMBER OF SIGMAS CONSIDERED FOR REJECTION OF OBSERVATIONS DURING THE FIRST FILTERING. CT(1-9) REFER TO DECLINATION,RIGHT ASCENSION, ELEVATION,AZIMUTH,RANGE,RANGE RATE,ELEVATION RATE,AZIMUTH RATE AND RANGE ACCELERATION,RESPECTIVELY	1-8 9-16 17-24 25-32 33-40 41-48 49-56 57-64 65-72
10	A) ELEMIN	MINIMUM ELEVATION ANGLE ALLOWED (DEGREES)	1-15
	B) ELEMAX	MAXIMUM ELEVATION ANGLE ALLOWED (DEGREES)	16-30
	*** INPUT CARD 10 IF AND ONLY IF NOB IS EQUAL TO 1		
11	ZONHAR(2-6)	COEFFICIENTS OF ZONAL HARMONICS J(2)	1-15
		J(3)	16-30
		J(4)	31-45
		J(5)	46-60
		J(6)	61-75

CARD	VARIABLE	DEFINITION	COLUMNS
12	A) REARTH	MEAN EQUATORIAL EARTH RADIUS (KM)	1-15
	B) F	FLATTENING OF THE EARTH	16-30
	C) OMU	EARTH S GRAVITATIONAL NUMBER (KM**3/SEC**2)	3131-45

**** INPUT CARDS 11,12 IF AND ONLY IF MERASE IS EQUAL TO 1
IF CARDS 11,12 ARE NOT INPUT THEN THE PROGRAM WILL SET
ZONHAR(2-6) =.10827E-2, -2.4E-6, -1.6E-6, -.02E-6, .7E-6
RESPECTIVELY, AND
REARTH =6378.165, F =.00335233, OMU =398603.20

CARDS 13 AND 14 REFER TO EPHEMERIS PRINTOUT

CARD	VARIABLE	DEFINITION	COLUMNS
13	A) DPRINT	PRINT INTERVAL (SECONDS)	1-15

*** THE FOLLOWING 6 VARIABLES REPRESENT THE INITIAL PRINT TIME
(DATE,TIME OF DAY) OF THE EPHEMERIS.

CARD	VARIABLE	DEFINITION	COLUMNS
	B) JMOPRT(1)	MONTH (FIXED POINT)	17-18
	C) JDYPRT(1)	DAY (FIXED POINT)	20-21
	D) JYRPRT(1)	YEAR,LAST 2 DIGITS OF 19XX (FIXED POINT)	23-24
	E) HRPRT(1)	HOUR OF THE FORM XX.0	26-29
	F) XMIPRT(1)	MINUTE OF THE FORM XX.0	31-34
	G) SECPRT(1)	SECOND OF THE FORM XX.XXX	36-41

*** THE FOLLOWING 6 VARIABLES REPRESENT THE FINAL PRINT TIME
(DATE,TIME OF DAY) OF THE EPHEMERIS.

CARD	VARIABLE	DEFINITION	COLUMNS
	H) JMOPRT(2)	MONTH (FIXED POINT)	43-44
	I) JDYPRT(2)	DAY (FIXED POINT)	46-47
	J) JYRPRT(2)	YEAR,LAST 2 DIGITS OF 19XX (FIXED POINT)	49-50
	K) HRPRT(2)	HOUR OF THE FORM XX.0	52-55

ARD	VARIABLE	DEFINITION	COLUMNS
	L) XMIPRT(2)	MINUTE OF THE FORM XX.0	57-60
	M) SECPRT(2)	SECOND OF THE FORM XX.XXX	62-67

```
*** EXAMPLE IF THE VARIABLES  A) - M) ON CARD 13 WERE
  60.0  6 21 65  2.0  50.0 0.0  6 21 65  23.0 50.0 10.0
THIS WOULD MEAN TO  PRINT EVERY 60 SECONDS (DPRINT)
 FROM    JUNE 21,1965   AT  2(HR)  50(MIN)  0(SEC.)
 TO      JUNE 21,1965   AT 23(HR)  50(MIN) 10(SEC.)
```

N) NOSPRI — NUMBER OF SPECIAL PRINT TIMES REQUESTED. MUST BE LESS THAN 21 (FIXED POINT) — 69-70

O) JTYPRT — INDICATES TYPE OF EPHEMERIS PRINT-OUT REQUESTED — 73

=0,NO EPHEMERIS. IN THIS CASE ALL VARIABLES ON CARD 13 MAY BE INPUT AS ZERO.

=1,PRINT POSITION AND VELOCITY
=2,PRINT POSITION,VELOCITY AND OSCULATING ELEMENTS
=3,PRINT POSITION,VELOCITY,OSCULATING ELEMENTS AND STATION OBSERVATION DATA.
=4,PRINT POSITION,VELOCITY AND STATION OBSERVATION DATA.
=5,PRINT STATION OBSERVATION DATA

P) KEYTAP — INDICATES TYPE OF EPHEMERIS TAPE REQUIRED — 75-76

=-1,BCD TAPE ONLY
= 0,BINARY AND BCD TAPE
= 1,BINARY TAPE ONLY

THE BCD TAPE IS WRITTEN ON U02,
THE BINARY TAPE IS WRITTEN ON U08(USE 800 BPI DENSITY TAPE)
IF KEYTAP =0 OR 1, THEN THE BINARY TAPE WILL CONTAIN ALL THE POSSIBLE DATA AT ANY PRINT TIME I.E. IT ASSUMES JTYPRT =3

CARD	VARIABLE	DEFINITION	COLUMNS
14	SPECIAL PRINT TIMES (DATE,TIME OF DAY) INPUT IF NOSPRI IS GREATER THAN ZERO.		
	A) JSPMO(I)	MONTH (FIXED POINT)	2-3
	B) JSPDA(I)	DAY (FIXED POINT)	5-6
	C) JSPYR(I)	YEAR,LAST 2 DIGITS OF 19XX (FIXED POINT)	8-9
	D) SPHR(I)	HOUR OF THE FORM XX.0	11-14
	E) SPMI(I)	MINUTE OF THE FORM XX.0	16-19
	F) SPSEC(I)	SECOND OF THE FORM XX.XXX	21-26

*** I=1,...,NOSPRI
THESE SETS OF SPECIAL PRINT TIME MUST FALL WITHIN THE TIME INTERVAL DEFINED BY VARIABLES B) - M) ON CARD 13

*** EXAMPLE, IF ON THE ABOVE EXAMPLE NOSPRI=1 AND CARD 14 CONTAINS 6 21 65 5.0 6.0 12.398,THEN A PRINTOUT WOULD ALSO OCCUR FOR JUNE 21,1965 AT 5(HR) 6(MIN) 12.398(SEC)

CARD	VARIABLE	DEFINITION	COLUMNS
15	OBSERVATION CARDS.MUST BE INPUT IN INCREASING ORDER WITH RESPECT TO TIME. CARDS OUT OF SEQUENCE WILL BE REJECTED. DECIMAL POINTS ARE NOT PUNCHED ON THESE CARDS.THEY ARE IMPLIED BY THE FORTRAN FORMAT.		
	A) MERASE(1)	SATELLITE NUMBER	2-6
	B) MOBS(1)	STATION NUMBER	7-9
	C) MOBS(2)	LAST 2 DIGITS OF YEAR 19XX	10-11
	D) DAYS	DAY OF YEAR	12-14
	E) ZDAT(1)	HOUR OF DAY	15-16
	F) ZDAT(2)	MINUTE OF HOUR	17-18

CARD	VARIABLE	DEFINITION	COLUMNS
G)	ZDAT(3)	SECOND OF MINUTE. DECIMAL POINT IMPLIED BETWEEN COLUMNS 20 AND 21	19-23
H)	MERASE(5)	FIRST DIGIT OF ELEVATION OR DECLINATION.(DEG) USE AN OVERPUNCH (11 PUNCH) FOR NEGATIVE QUANTITIES	24
I)	OBSM(1)	REMAINING DIGITS OF ELEVATION OR DECLINATION. DECIMAL POINT IMPLIED BETWEEN COLUMN 25 AND 26.	25-29
J)	ERASE(1)	FIRST 2 DIGITS OF AZIMUTH (DEG), OR HOUR OF RIGHT ASCENSION	31-32
K)	ERASE(2)	NEXT 2 DIGITS OF AZIMUTH.DECIMAL POINT IMPLIED BETWEEN COLUMNS 33 AND 34, OR MINUTE OF RIGHT ASCENSION	33-34
L)	ERASE(3)	LAST 3 DIGITS OF ELEVATION,OR SECONDS OF RIGHT ASCENSION.DECIMAL POINT IMPLIED BETWEEN COLUMNS 36 AND 37	35-37
M)	OBSM(3)	RANGE (KM)	39-45
N)	IEX	EXPONENT AN EXPONENT OF ZERO (0) IMPLIES THE DECIMAL POINT BETWEEN COLUMNS 40 AND 41,AN EXPONENT OF ONE (1) IMPLIES THE DECIMAL POINT BETWEEN COLUMNS 41 AND 42 ETC. THE MAXIMUM ALLOWABLE EXPONENT IS FIVE (5)	46
O)	OBSM(4)	FIRST DIGIT OF RANGE RATE (KM/SEC). USE AN OVERPUNCH (11 PUNCH) FOR NEGATIVE QUANTITIES	48
P)	ERASE(5)	REMAINING DIGITS OF RANGE RATE.DECIMAL POINT IMPLIED BETWEEN COLUMNS 49 AND 50	49-54
Q)	OBSM(5)	FIRST DIGIT OF ELEVATION RATE (DEG/SEC). USE AN OVERPUNCH FOR NEGATIVE QUANTITIES	56
R)	ERASE(6)	REMAINING DIGITS OF ELEVATION RATE.DECIMAL POINT IMPLIED BETWEEN COLUMNS 56 AND 57	57-60

CARD	VARIABLE	DEFINITION	COLUMNS
S)	OBSM(6)	FIRST DIGIT OF AZIMUTH RATE (DEG/SEC) USE AN OVERPUNCH FOR NEGATIVE QUANTITIES	62
T)	ERASE(7)	REMAINING DIGITS OF AZIMUTH RATE.DECIMAL POINT IMPLIED BETWEEN COLUMNS 62 AND 63	63-66
U)	OBSM(7)	FIRST DIGIT OF RANGE ACCELERATION (KM/SEC^2) USE AN OVERPUNCH FOR NEGATIVE QUANTITIES	68
V)	ERASE(8)	REMAINING DIGITS OF RANGE ACCELERATION.DECI-MAL POINT IMPLIED COLUMNS 67 AND 68	69-72
W)	OBSNO	CODE WHICH DESIGNATES TYPE OF SIMULTANEOUS OBSERVATIONS IS IN COLUMN 75.THIS CODE WILL BE REDEFINED AND STORED IN THE VARIABLE NTP. (SEE NTP IN LIST OF SYMBOLS)	75-76

COL.75	TYPES OF OBSERVATIONS	NTP
=1	ELEVATION AND AZIMUTH	2
=2	ELEVATION,AZIMUTH AND RANGE	3
=3	ELEVATION,AZIMUTH,RANGE AND RANGE RATE	4
=4	ELEVATION,AZIMUTH,RANGE,RANGE RATE, ELEVATION RATE,AZIMUTH RATE AND RANGE ACCELERATION	7
=5	DECLINATION AND RIGHT ASCENSION	1

THE PROGRAM CONVERTS THE RIGHT ASCENSION TO RADIANS BY THE EQUATION:

```
OBSM(2)=(ERASE(1) + ERASE(2)/60.0 +
        ERASE(3)/3600.0)*15.0*.017453292
```

CODE OF THE CELESTIAL REFERENCE SYSTEM(YEAR OF EQUINOX) IS IN COLUMN 76. THIS IS USED ONLY WHEN THE DECLINATION OR RIGHT ASCENSION ARE INPUT.THE CODE IS AS FOLLOWS

COL.76	YEAR
=0	YEAR OF DATE (MOBS(2))
=1	1900.0
=2	1920.0
=3	1950.0
=4	1975.0
=5	2000.0
=6	1850.0
=7	1855.0
=8	1875.0
=9	1960.0

THIS CODE NUMBER WILL BE STORED IN THE VARIABLE NEQ (SEE NEQ IN LIST OF SYMBOLS)

16 A CARD WITH THE WORD ENDDAT IN COLUMNS 73-78. THIS CARD FOLLOWS THE LAST OBSERVATION CARD 73-78

17 A CARD WITH THE PHRASE:END (IN COLUMNS 1-3) OF (IN COLUMNS 5-6) PROBLEM (IN COLUMNS 8-14) 1-14

IV. PROGRAM OUTPUT

A. OUTPUT OF THE INPUT(EXCEPT FOR THE OBSERVATION CARDS)

THE OUTPUT FOR THIS SECTION IS DONE IN MAIN PROGRAM AFILT2.

```
INITIAL CONDITIONS

                                                REVOLUTION NUMBER-IREVO
DATE AND TIME
MOBS(2)    MOBS(3)    MOBS(4)    ZDAT(1)    ZDAT(2)    ZDAT(3)

ORBITAL ELEMENTS
AXSEMI     ECCEN      OINCL      WASC       WPERI      XMEAN

POSITION AND VELOCITY ERRORS
PMAT(1,1)    PMAT(2,2)   PMAT(3,3)    PMAT(4,4)    PMAT(5,5)    PMAT(6,6)

MEASUREMENT ERRORS
QP(1)      QP(2)      Q(1)       Q(2)       Q(3)       Q(4)
Q(5)       Q(6)       Q(7)

NUMBER OF SIGMAS TOLERATED  CT(1-9)

SATELLITE DATA                   EARTH DATA
OMSAT      SSAT       CDRAG      REARTH     F          OMU

ZONAL HARMONICS(2-6)     ZONHAR(1-5)

PROGRAM CONTROLS  NOB  NAT  MERASE(1)  KOBSPR  KCOUNT  ISMOOH  NSTPRT
                  PASS   TIMTOL

STATION DATA
NUMSTA   NSG       SLON      SLAT      PHILAT    ALT       SRAD

EPHEMERIS PRINTOUT DATA
JMOPRT(1)  JDAPRT(1)  JYRPRT(1)  HRPRT(1)   XMIPRT(1)  SECPRT(1)
JMOPRT(2)  JDAPRT(2)  JYRPRT(2)  HRPRT(2)   XMIPRT(2)  SECPRT(2)

PRINTOUT CODE- JTYPRT   TAPE INDICATOR- KEYTAP   PRINT INTERVAL- DPRINT

SPECIAL PRINTOUT TIMES (IF ANY)
JSPMO      JSPDA      JSPYR      SPHR       SPMI       SPSEC

INITIAL COMPUTATIONS
PERIOD     ERASE(1)     TNEXOS
PNODAL
```

REMARKS 1) THE DIMENSION OF ALT,STATION ALTITUDE,IS IN KILOMETERS(IT IS INPUT IN METERS)

2) THE VARIABLES SLAT,SRAD,PERIOD AND PNODAL ARE COMPUTED. (SEE THE LISTING OF SYMBOLS FOR THEIR DEFINITIONS)

3) ERASE(1) IS THE COMPUTED ECCENTRICITY (DEFINED IN SURROUTINE KEPLER)

4) THE REMAINING VARIABLES ARE DEFINED IN THE INPUT LISTING.

5) IF ANY ERRORS IN THE INPUT,THE PROGRAM WILL PRINTOUT AN APPROPRIATE MESSAGE AND CONTINUE TO THE NEXT PROBLEM.

B.FILTERING OUTPUT

THE FILTERING OUTPUT IS DONE IN MAIN PROGRAM RFILT2.EACH PAGE IS PROPERLY LABELED AND THE PHRASE FORWARD FILTERING (OR BACKWARD FILTERING) IS WRITTEN ON IT.

```
DJULN     MOBS(2)  MOBS(3)  MOBS(4)  ZDAT(1)   ZDAT(2)   ZDAT(3)  NUMSTA
DV(1)       DV(2)       DV(3)       DVP(1)      DVP(2)      DVP(3)
ERASE(1)    ERASE(2)    ERASE(3)    ERASE(4)    ERASE(5)    ERASE(6)
ERASE(7)    ERASE(8)    ERASE(9)    ERASE(10)   ERASE(11)   ERASE(12)
                     MEASURED   COMPUTED   DIFFERENCE      TOLERANCE
ELEVATION OR         OBSM(1)    OBSC(1)    DIFR(1)         TOLER(1)
DECLINATION
AZIMUTH OR           OBSM(2)    OBSC(2)    DIFR(2)         TOLER(2)
RIGHT ASCENSION
RANGE                OBSM(3)    OBSC(3)    DIFR(3)         TOLER(3)
RANGE RATE           OBSM(4)    OBSC(4)    DIFR(4)         TOLER(4)
ELEVATION RATE       OBSM(5)    OBSC(5)    DIFR(5)         TOLER(5)
AZIMUTH RATE         OBSM(6)    OBSC(6)    DIFR(6)         TOLER(6)
RANGE ACCELERATION   OBSM(7)    OBSC(7)    DIFR(7)         TOLER(7)
```

REMARKS 1) DJULN IS THE MODIFIED JULIAN DATE OF THE OBSERVATION.
MOBS(2-4) REPRESENT THE DATE OF THE OBSERVATION.
ZDAT(1-3) REPRESENT THE TIME OF DAY OF THE OBSERVATION.
NUMSTA IS THE STATION NUMBER.

2) DV(1-3) ARE THE X,Y,Z COORDINATES OF THE UPDATED POSITION VECTOR.(IN KILOMETERS)
DVP(1-3) ARE THE $\dot{X}$,$\dot{Y}$,$\dot{Z}$ COORDINATES OF THE UPDATED VELOCITY VECTOR.(IN KILOMETERS/SECOND)

3) ERASE(1-6) ARE THE CORRECTIONS TO THE POSITION AND VELOCITY VECTORS.(IN KILOMETERS AND KILOMETERS/SECOND,RESPECTIVELY)
ERASE(7-12) ARE THE STANDARD DEVIATIONS OF THE POSITION AND VELOCITY ERRORS.(IN KILOMETERS AND KILOMETERS/SECOND, RESPECTIVELY)
ERASE(1-12) ARE DEFINED IN BFILT2.

4) THE ANGULAR DATA OF THE OBSERVATIONS ARE OUTPUT IN DEGREES OR DEGREES/SECOND.
THE RANGE IS IN KILOMETERS.
THE RANGE RATE IS IN KILOMETERS/SECOND.
THE RANGE ACCELERATION IS IN KILOMETERS/SECOND^2.

5) IF AN OBSERVATION CARD IS REJECTED,THE FOLLOWING MESSAGE WILL BE PRINTED OUT:

FOLLOWING CARD DISCARDED.OBSERVATION DEVIATES FROM THEORETICAL VALUE BEYOND ALLOWABLE LIMIT.

THEN THE PROGRAM PRINTS THE SAME INFORMATION AS ABOVE, EXCEPT FOR THE VARIABLES ERASE(1-12)

6) IF THE PROGRAM ITERATES,THEN THE PROGRAM WILL PRINTOUT:

```
ITERATION CHECK ON DELTA POSITION AND VELOCITY FAILED.
POS=DV(1)     DV(2)     DV(3)       VEL=DVP(1)   DVP(2)    DVP(3)
DEL=ERASE(1) ERASE(2) ERASE(3)    DEL=ERASE(4) ERASE(5) ERASE(6)
POSITION,VELOCITY,AND CORRECTION FOR PREVIOUS TIME
DV(1)      DV(2)      DV(3)      DVP(1)     DVP(2)     DVP(3)
RASE(1)    RASE(2)    RASE(3)    RASE(4)    RASE(5)    RASE(6)
```

RASE(1-6) ARE THE CORRECTIONS TO THE PREVIOUS POSITION AND VELOCITY VECTOR.(IN KILOMETERS AND KILOMETERS/SECOND)

7) AT THE END OF EACH FILTERING PHASE THE PROGRAM PRINTS:

```
COVARIANCE MATRIX
PMAT(I,J)  I=1,...,6   J=1,...,6
NEW MEASUREMENT ERRORS
ERASE(1-9)
NUMBER OF SIGMAS TOLERATED  CT(1-9)
```

```
          PMAT IS THE COVARIANCE MATRIX.
          ERASE(1-9) ARE THE IMPROVED STANDARD OBSERVATION ERRORS.
          (SEE EQUATION A.15)
          CT(1-9) ARE THE RECOMPUTED NUMBER OF SIGMAS.(SEE EQUATION
          A.160)
          THE PROGRAM ALSO PRINTS THE COMPUTING TIME FOR THIS PHASE
          IN MINUTES
TIME FOR THIS PHASE= ERASE(1) MIN.

        8) IF THERE IS OVERFLOW OR A DIVISION BY ZERO,THE PROGRAM
          PRINTS AN APPROPRIATE MESSAGE,DUMPS CORE,AND GOES TO THE
          NEXT PROBLEM.

        9) THE DIFFERENTIAL EQUATION SUBROUTINE PRINTS THE FOLLOW-
          ING ERROR MESSAGE
DENSIT SUBROUTINE ERROR NO.RHO.  PROGRAM WILL GO TO NEXT PROBLEM.
          IF RHO =-1.0,THE EXOSPHERIC TEMPERATURE IS OUTSIDE
                    OF THE 500°K - 2400°K RANGE.
          IF RHO = 0.0,THE ALTITUDE IS LESS THAN 120.0(KM).

       10) IF THE DIAGONAL ELEMENTS OF THE COVARIANCE MATRIX ARE
          NEGATIVE,THEN THE PROGRAM PRINTS
COVARIANCE MATRIX BECAME NEGATIVE.
          IF THIS NUMERICAL PROBLEM REOCCURS AFTER DIAGONALIZATION,
          THEN THE PROGRAM WILL DUMP CORE,AND GO TO THE NEXT
          PROBLEM.
          (SEE EQUATION 51,REFERENCE 1  AND SUBROUTINE DIACHK)


       11) IF THE SMOOTHING OPTION HAS BEEN REQUESTED,THE PROGRAM
          WILL PRINT ON THE SYSTEM OUTPUT TAPE
SMOOTHING DATA. POINT TO BE SMOOTHED AT  OLDDAY,OLDTIM
          EACH TIME THE PROGRAM COMPUTES THE SMOOTHING EQUATIONS
          THE PROGRAM PRINTS
MOD.JUL.DATE = DJULN    TIME = TNORMN(SEC)
DIFFERENCES BETWEEN STORED AND INTEGRATED VALUES IN POSITION AND VELOCITY
ERASE(1)   ERASE(2)   ERASE(3)   ERASE(4)   ERASE(5)   ERASE(6)
CORRECTIONS IN POSITION AND VELOCITY AT THE INITIAL DATE (I.E.OLDDAY,OLDTIM)
ERASE(1)   ERASE(2)   ERASE(3)   ERASE(4)   ERASE(5)   ERASE(6)
NEW POSITION AND VELOCITY AT THE INITIAL DATE
DV(1)      DV(2)      DV(3)      DVP(1)     DVP(2)     DVP(3)
          OLDDAY IS THE MODIFIED JULIAN DATE OF THE LAST OBSERVATION
          CARD WHICH HAS BEEN STORED FOR SMOOTHING
          OLDTIM IS THE TIME OF DAY IN SECONDS CORRESPONDING TO
          OLDDAY.
          THIS IS PRINTED IN SUBROUTINE ORBINT
```

C.EPHEMERIS OUTPUT

THIS OUTPUT IS WRITTEN ON A BCD TAPE(WHEN REQUESTED BY CUSTOMER) AND IS PRINTED OUT IN SUBROUTINE PROUT.EACH PAGE IS PROPERLY LABELED AND THE WORD EPHEMERIS IS WRITTEN ON IT.

DAYJL KMOOUT KDAOUT KYROUT KHROUT KMIOUT SECOUT TNORMO IREV

THE REMAINDER OF THE OUTPUT IS A FUNCTION OF THE VARIABLE JTYPRT.(SEE INPUT LISTING)

POSITION AND VELOCITY OUTPUT

DV(1)	DV(2)	DV(3)	DVP(1)	DVP(2)	DVP(3)			
ALTID	RADPRT	VTCTPR	GEOCEN	GEODET	OLAMO	MSTHR	MSTMIN	STSECO

OSCULATING ELEMENTS OUTPUT

AXIMAJ	ECCENT	OINCLI	ASCNOD	PERIGE	OMEANA

STATION OBSERVATION DATA OUTPUT

NUMSTA		ELRATE	AZRATE	RARATE	DCRATE
ELEVAT	AZIMUT	RANGES	RANRAT	RTASC	DECLIN

REMARKS 1) THE BINARY TAPE FORMAT PRODUCED BY THE PROGRAM IS AS FOLLOWS

FIRST RECORD IDENTIFICATION RECORD

WORD	DEFINITION
1. KF7	7,NUMBER OF WORDS REMAINING IN THIS RECORD
2. NOSAT	SATELLITE NUMBER
3. TIMSEC(1)	TIME OF DAY OF INITIAL PRINT TIME (SEC)
4. DJUPRT(1)	MODIFIED JULIAN DATE OF FINAL PRINT TIME
5. TIMSEC(2)	TIME OF DAY OF FINAL PRINT TIME (SEC)
6. DJUPRT(2)	MODIFIED JULIAN DATE OF FINAL PRINT TIME
7. DPRINT	PRINT INTERVAL (SEC)
8. NOSPRT	NUMBER OF SPECIAL PRINT TIMES

SECOND RECORD   DATA RECORD

WORD	DEFINITION
1. MERASE(1)	NUMBER OF WORDS REMAINING IN THIS RECORD =32 + 11*IJ
2. DAYJL	MODIFIED JULIAN DATE OF THE EPHEMERIS PRINT TIME
3. KMOOUT	CALENDAR MONTH
4. KDAOUT	CALENDAR DAY
5. KYROUT	CALENDAR YEAR (LAST 2 DIGITS OF 19XX)
6. KHROUT	HOUR OF DAY
7. KMIOUT	MINUTE OF HOUR
8. SECOUT	SECONDS OF MINUTE
9. TNORMO	TIME OF DAY IN SECONDS CORRESPONDING TO DAYJL
10. DV(1)	X COORDINATE OF POSITION VECTOR (KM)
11. DV(2)	Y COORDINATE OF POSITION VECTOR (KM)
12. DV(3)	Z COORDINATE OF POSITION VECTOR (KM)
13. DVP(1)	$\dot{X}$ COORDINATE OF VELOCITY VECTOR (KM/SEC)
14. DVP(2)	$\dot{Y}$ COORDINATE OF VELOCITY VECTOR (KM/SEC)
15. DVP(3)	$\dot{Z}$ COORDINATE OF VELOCITY VECTOR (KM/SEC)
16. ALTIO	SATELLITE ALTITUDE (KM)
17. RADPRT	DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM)
18. VTOTPR	VELOCITY (KM/SEC)
19. GEOCEN	GEOCENTRIC LATITUDE (DEG)
20. GEODET	GEODETIC LATITUDE (DEG)
21. OLAMO	SATELLITE LONGITUDE (DEG)
22. MSTHR	HOUR OF GREENWICH MEAN SIDEREAL TIME
23. MSTMIN	MINUTE OF GREENWICH MEAN SIDEREAL TIME
24. STSECO	SECONDS OF GREENWICH MEAN SIDEREAL TIME
25. AXIMAJ	SEMI-MAJOR AXIS (KM)
26. ECCENT	ECCENTRICITY
27. OINCLI	INCLINATION (DEG)
28. ASCNOD	RIGHT ASCENSION OF ASCENDING NODE (DEG)
29. PERIGE	ARGUMENT OF PERIGE (DEG)
30. OMEANA	MEAN ANOMALY (DEG)
31. IREV	REVOLUTION NUMBER

32. IJ	NUMBER OF STATIONS IN THIS DATA RECORD OBS-ERVING THE SATELLITE ($IJ \leq 10$)
33. ITYPE	=1,FINAL DATA RECORD FOR THIS EPHEMERIS PRINT TIME
	=-1,ANOTHER DATA RECORD TO FOLLOW FOR THIS EPHEMERIS PRINT TIME
34. NUMSTA	STATION NUMBER
35. ELRATE	ELEVATION RATE (DEG/SEC)
36. AZRATE	AZIMUTH RATE (DEG/SEC)
37. RARATE	RIGHT ASCENSION RATE (DEG/SEC)
38. DCRATE	DECLINATION RATE (DEG/SEC)
39. ELEVAT	ELEVATION (DEG)
40. AZIMUT	AZIMUTH (DEG)
41. RANGES	RANGE (KM)
42. RANRAT	RANGE RATE (KM/SEC)
43. RIASC	RIGHT ASCENSION (DEG)
44. DECLIN	DECLINATION (DEG)

THE SEQUENCE OF WORDS 34 TO 44 IS REPEATED IJ TIMES.

THIRD RECORD   DATA RECORD WHICH CONTAINS STATION OBSERVATION DATA ONLY.THIS RECORD IS WRITTEN WHENEVER THE FIRST DATA RECORD DOES NOT CONTAIN ALL OF THE STATION OBSERVATION DATA.

WORD	DEFINITION
1. MERASE(1)	NUMBER OF WORDS REMAINING IN THIS RECORD =2 + 11*IJ
2. IJ	SEE WORD 32 ABOVE
3. ITYPE	SEE WORD 33 ABOVE
4. - 14.	SEE WORDS 34 - 44 ABOVE

THE SEQUENCE OF WORDS 4 TO 14 IS REPEATED IJ TIMES.IF ITYPE IS STILL EQUAL TO -1,THEN THIS DATA RECORD IS REPEATED.

THE SECOND RECORD (AND THE THIRD RECORD WHENEVER NECESSARY) IS REPEATED FOR EVERY PRINT TIME.

FOURTH RECORD   IDENTIFICATION RECORD FOR THE END OF THE PROBLEM.

WORD	DEFINITION
1. KF1	1
2. BLANKS	OCTAL NUMBER 606060606060

AN END OF FILE FOLLOWS THIS RECORD.

2) IF A BINARY TAPE HAS BEEN REQUESTED,THE PROGRAM WILL PRINT ON THE SYSTEM OUTPUT TAPE

```
AXIMAJ     ECCEN     OINCLI     ASCNOD     PERIGE     OMEANA
IREV
```

THESE ARE THE OSCULATING ELEMENTS AND REVOLUTION NUMBER FOR THE FINAL PRINT TIME.

3) IF ANY ERROR MESSAGES, THE EPHEMERIS OUTPUT WILL NOT BE COMPLETE.

4) IF THERE IS MORE THAN ONE FILTERING AND ALL OBSERVATION CARDS WERE REJECTED,THEN THERE IS NO EPHEMERIS COMPUTATION.

D. SAMPLE OF OUTPUT
OUTPUT OF INPUT

```
PREPARED BY/FOR THE DATA ANALYSIS BRANCH (CRMXA), AIR FORCE CAMBRIDGE RESEARCH LABORATORIES TELEPHONE 274-6100,X4395
 SAMPLE OUTPUT                                                 SATELLITE    11    FORWARD  FILTERING   PAGE   1

INITIAL CONDITIONS

DATE AND TIME                                                   REVOLUTION NUMBER =   200
    YEAR       MONTH        DAY        HOUR        MINUTE       SECOND
     62         10           7          0.           0.          0.000

ORBITAL ELEMENTS
    S.M. AXIS(KM)       ECCENTRICITY         INCLINATION(DEG)     R.A.ASC.NODE(DEG)    ARG.PERI(DEG)        MEAN ANOM.(DEG)
    0.83037619E 04      0.16424700E 00       0.32877100E 02       0.19854130E 03       0.30696100E 03       0.25867512E 03

POSITION AND VELOCITY ERRORS
    X (KM)              Y (KM)               Z (KM)               XDOT (KM/SEC)        YDOT (KM/SEC)        ZDOT (KM/SEC)
    0.50000000E 01      0.50000000E 01       0.50000000E 01       0.50000000E-02       0.50000000E-02       0.50000000E-02

MEASUREMENT ERRORS
DEC.(SEC OF ARC)    RT.ASC.(SEC OF ARC)    ELE.(SEC OF ARC)     AZI.(SEC OF ARC)     RANGE(KM)            RANGE RATE(KM/SEC)
    0.60000000E 02      0.60000000E 02       0.36000000E 03       0.36000000E 03       0.10000000E 01       0.10000000E-01
ELE.RATE(SEC OF ARC/SEC)    AZI.RATE(SEC OF ARC/SEC)      RANGE ACCELERATION(KM/SEC**2)
        0.                          0.                          0.

NUMBER OF SIGMAS TOLERATED   100.000   100.000   100.000   100.000   100.000   100.000   100.000   100.000   100.000

SATELLITE DATA                                                EARTH DATA
  MASS (KG)             AREA (M**2)          DRAG COEFF.          EQ. RADIUS (KM)      FLATTENING           MU (KM**3/SEC**2)
    0.93895201E 01      0.20268299E 00       0.22000000E 01       0.63781650E 04       0.33523300E-02       0.39860320E 06

ZONAL HARMONICS (2-6) =      0.10827000E-02     -0.24000000E-05     -0.16000000E-05     -0.20000000E-07      0.70000000E-06

PROGRAM CONTROLS       NOB = 0  NAT = 0  NERASE = 0  KOBSPR = 1  KCOUNT =   0  ISMOOH = 0  NSTPRT = 4  PASS = 1.0
    SYSTEM TIMING ERROR =    0.000 (SEC)

STATION DATA
  NUMBER       NSG     LONGITUDE (DEG)      GEOC.LAT. (DEG)      GEOD.LAT. (DEG.)     ALTITUDE (KM)        RADIUS (KM)
    35          1      -0.13678190E 03      -0.30931775E 02      -0.31101700E 02       0.16200000E 00       0.63726564E 04
    42          1      -0.52519000E 02       0.29472634E 02       0.29637700E 02       0.15960000E 01       0.63745652E 04
    47          1      -0.20374210E 03       0.20583096E 02       0.20710000E 02       0.30480000E 01       0.63785584E 04
    34          1      -0.28247500E 02      -0.25808606E 02      -0.25959700E 02       0.15440000E 01       0.63756396E 04

EPHEMERIS PRINTOUT DATA

                       MONTH DAY YEAR     HR. MIN. SEC.
    START PRINT TIME    10    7   62       0.  0.  0.000
    END PRINT TIME      10    7   62      19.  8.  0.000

    PRINTOUT CODE = 3         TAPE INDICATOR = -1         PRINT INTERVAL =   0.14400000E 05

    SPECIAL PRINTOUT TIMES      MONTH DAY YEAR      HR. MIN. SEC.
                                 10    7   62        6. 48. 22.546

  INITIAL COMPUTATIONS
  PERIOD = 0.75304633E 04 SEC.      ECCENTRICITY = 0.16424703E 00      TEMPERATURE = 0.76029437E 03 DEG K
```

Filtering Output

```
PREPARED BY/FOR THE DATA ANALYSIS BRANCH (CRMXA), AIR FORCE CAMBRIDGE RESEARCH LABORATORIES TELEPHONE 274-6100,X4395
  VANGUARD  7044 TEST                                                         SATELLITE    11    FORWARD FILTERING   PAGE   3
MOD  JULIAN DATE     YEAR     MONTH      DAY      HOUR     MINUTE       SECOND      STA.NO.
        X                       Y                   Z                     XDOT                  YDOT                  ZDOT
     DELTA X                 DELTA Y             DELTA Z              DELTA XDOT            DELTA YDOT            DELTA ZDOT
     SIGMA X                 SIGMA Y             SIGMA Z              SIGMA XDOT            SIGMA YDOT            SIGMA ZDOT

     4662.0          62       10        7       5.       36.      10.538          47
     0.41392284E 04     -0.68531208E 04     0.50365278E 04     0.55303390E 01     0.23581174E 01     -0.35446719E 00
     0.11363580E 01      0.11461680E 01     0.12609612E 01    -0.62295844E-03     0.89949849E-03      0.28568788E-03
     0.62586595E 00      0.62167542E 00     0.95926502E 00     0.55431104E-03     0.62927186E-03      0.72191224E-03
      DECLINATION     MEAS.= 0.53707199E 02   COMP.= 0.53686307E 02   DIFF.= 0.20892695E-01   TOLE.= 0.76753649E 01
      RIGHT ASCEN.           0.29509208E 03          0.29504957E 03          0.42507682E-01          0.35719075E 02

     4662.0          62       10        7       5.       36.      26.539          47
     0.42274612E 04     -0.68149685E 04     0.50305670E 04     0.54988592E 01     0.24095475E 01     -0.39239128E 00
    -0.70572373E-02      0.80741595E-02     0.14788113E-01    -0.32311837E-06     0.38965553E-05      0.91665889E-05
     0.45745655E 00      0.48101502E 00     0.74289662E 00     0.53167470E-03     0.57351615E-03      0.62104637E-03
      DECLINATION     MEAS.= 0.53566600E 02   COMP.= 0.53566019E 02   DIFF.= 0.57971230E-03   TOLE.= 0.23373009E 01
      RIGHT ASCEN.           0.29757625E 03          0.29757639E 03         -0.14684907E-03          0.23453184E 01

     4662.0          62       10        7      16.        4.      44.965          42
     0.47086642E 04     -0.65981040E 04     0.49479195E 04     0.53431113E 01     0.26348650E 01     -0.66386403E 00
    -0.38517350E 01     -0.19589405E 01     0.19837250E 00     0.15813901E-02    -0.22213400E-02      0.16749044E-02
     0.70190867E 00      0.50373968E 00     0.57656857E 00     0.47500258E-03     0.70560041E-03      0.70896947E-03
      DECLINATION     MEAS.= 0.34836300E 02   COMP.= 0.34840930E 02   DIFF.=-0.46304414E-02   TOLE.= 0.95015381E 01
      RIGHT ASCEN.           0.29680125E 03          0.29689705E 03         -0.95803648E-01          0.12664589E 03

     4662.0          62       10        7      16.       58.       8.184          35
     0.30285992E 04      0.63407143E 04    -0.33873670E 04    -0.70499916E 01     0.97633500E 00     -0.18814410E 01
     0.76085665E 01     -0.71355051E 00     0.12520493E 01     0.28499006E-02     0.44643765E-02     -0.19363011E-02
     0.74610062E 00      0.47599588E 00     0.46900302E 00     0.37772673E-03     0.56018636E-03      0.51774572E-03
      DECLINATION     MEAS.=-0.26262000E 01   COMP.=-0.26365279E 01   DIFF.= 0.10327913E-01   TOLE.= 0.27680229E 01
      RIGHT ASCEN.           0.10625667E 03          0.10643589E 03         -0.17922160E 00          0.74648573E 01

     4662.0          62       10        7      16.       58.      36.183          35
     0.28305323E 04      0.63658547E 04    -0.34390659E 04    -0.71191832E 01     0.82625736E 00     -0.18004750E 01
     0.30484923E 00     -0.97591166E-01    -0.14814299E 00     0.10423144E-03     0.22244141E-03      0.44479626E-04
     0.56550287E 00      0.45597643E 00     0.38432081E 00     0.32691246E-03     0.48412550E-03      0.48479637E-03
      DECLINATION     MEAS.=-0.37140000E 01   COMP.=-0.36992425E 01   DIFF.=-0.14757477E-01   TOLE.= 0.19787680E 01
      RIGHT ASCEN.           0.11031292E 03          0.11032681E 03         -0.13894312E-01          0.22669671E 01

     4662.0          62       10        7      19.        6.      51.045          35
     0.15836618E 04      0.64234934E 04    -0.37115859E 04    -0.74519312E 01    -0.13201290E 00     -0.12398107E 01
     0.17951673E 01     -0.33287602E 00     0.60087918E 00    -0.93411303E-04     0.12968918E-02     -0.84047963E-03
    -0.34102105E 00      0.26450344E 00     0.25641557E 00     0.22204893E-03     0.39768213E-03      0.45626214E-03
      DECLINATION     MEAS.=-0.19973900E 02   COMP.=-0.20028552E 02   DIFF.= 0.54652185E-01   TOLE.= 0.25111733E 01
      RIGHT ASCEN.           0.60859581E 02          0.60948728E 02         -0.89146775E-01          0.52527008E 01

     4662.0          62       10        7      19.        7.       3.045          35
     0.14943573E 04      0.64215087E 04    -0.37260584E 04    -0.74688313E 01    -0.20241074E 00     -0.11990087E 01
     0.22103628E 00      0.22314066E-01     0.16001614E 00     0.60360456E-06     0.13771750E-03     -0.13526127E-03
     0.25353936E 00      0.24614434E 00     0.21175840E 00     0.22244299E-03     0.35764921E-03      0.44447199E-03
      DECLINATION     MEAS.=-0.21251200E 02   COMP.=-0.21274943E 02   DIFF.= 0.23742805E-01   TOLE.= 0.20747477E 01
      RIGHT ASCEN.           0.64451666E 02          0.64469841E 02         -0.18175134E-01          0.23353940E 01
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Ephemeris Output

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PREPARED BY/FOR THE DATA ANALYSIS BRANCH (CRMXA), AIR FORCE CAMBRIDGE RESEARCH LABORATORIES TELEPHONE 274-6100,X4395
 SAMPLE OUTPUT                                                    SATELLITE    11      EPHEMERIS       PAGE    2
 MOD. JULIAN DATE     MONTH DAY YEAR    HOUR MIN. SEC.       TIME (SEC.)           REVOLUTION
      X (KM)               Y (KM)               Z (KM)           XDOT (KM/SEC)         YDOT (KM/SEC)          ZDOT (KM/SEC)
   ALTITUDE (KM)        RADIUS (KM)        VTOTAL (KM/SEC)   G.C.LAT.(DEG)  G.D.LAT.(DEG)    LONG. (DEG)  GMST (H-M-S)
   S.M. AXIS (KM)       ECCENTRICITY        INCLIN. (DEG)     ASC. NODE (DEG)    ARG. PERI. (DEG)     MEAN ANOM. (DEG)
                                          DELEV. (DEG/SEC)   DAZI. (DEG/SEC)     DRTASC (DEG/SEC)     DDECL (DEG/SEC)
  ELEVATION (DEG)       AZIMUTH (DEG)       RANGE (KM)       DRANGE (KM/SEC)       RT. ASC. (DEG)        DECLIN. (DEG)

    4662.0           10    7  62       0   0    0.000         0.000              200
   0.78867854E 04    0.37477799E 04    -0.67915317E 03    -0.35018046E 01      0.43691005E 01     -0.34006741E 01
   0.23803059E 04    0.87583417E 04     0.65510501E 01    -4.447385       -4.469081        349.74279    1  0 39.234
   0.82858884E 04    0.16558234E 00     0.32908492E 02     0.19851404E 03      0.30704987E 03      0.25876455E 03
  STATION NO. =    34                   0.48453968E-01     0.27382616E-01      0.59875692E-01     -0.17200154E-01
   0.19123759E 02    0.31808642E 03     0.42720255E 04    -0.46524566E 01      0.35697515E 03      0.29391324E 02

    4662.0           10    7  62       4   0    0.000     14400.000              202
   0.91863341E 04    0.62559034E 03     0.14612104E 04    -0.50763112E 00      0.51541239E 01     -0.32699485E 01
   0.29451968E 04    0.93228339E 04     0.61249690E 01     9.017410         9.058205         71.42815    5  1 18.660
   0.83049387E 04    0.16339479E 00     0.32888762E 02     0.19810203E 03      0.30768943E 03      0.22759063E 03

    4662.0           10    7  62       6  48   22.546     24502.546              203
  -0.44385619E 04    0.41369248E 04    -0.34190084E 04    -0.59668301E 01     -0.51765626E 01      0.20163687E 01
   0.59153186E 03    0.69645240E 04     0.81526291E 01   -29.400919       -29.551731        340.51870    7 50  8.866
   0.83039936E 04    0.16439268E 00     0.32876732E 02     0.19768328E 03      0.30837726E 03      0.35069358E 03
  STATION NO. =    34                   0.21002386E 00    -0.46938212E-01      0.23171504E 00     -0.93985202E-01
   0.26259319E 02    0.24319360E 03     0.11553869E 04    -0.64491909E 01      0.71310769E 02     -0.33832020E 02

    4662.0           10    7  62       8   0    0.000     28800.000              204
   0.86269581E 04   -0.26655244E 04     0.33225233E 04     0.22166071E 01      0.48397592E 01     -0.25532449E 01
   0.32456532E 04    0.96212570E 04     0.59036695E 01    20.202034        20.284740        152.65817    9  1 58.086
   0.83036816E 04    0.16346867E 00     0.32888864E 02     0.19751309E 03      0.30869639E 03      0.19616372E 03
  STATION NO. =    47                  -0.89655603E-01     0.20196229E 00      0.87592846E-01     -0.49335866E-01
   0.75983905E 02    0.95814001E 02     0.32757572E 04     0.33270931E 00      0.34979329E 03      0.19251053E 02

    4662.0           10    7  62      12   0    0.000     43200.000              206
   0.64669780E 04   -0.54553083E 04     0.45905866E 04     0.44152973E 01      0.36452902E 01     -0.14238388E 01
   0.32524988E 04    0.96257818E 04     0.59000260E 01    28.483478        28.590337        235.80234   13  2 37.512
   0.83025714E 04    0.16362258E 00     0.32880650E 02     0.19691926E 03      0.30965136E 03      0.16479137E 03

    4662.0           10    7  62      16   0    0.000     57600.000              208
   0.31099961E 04   -0.72166470E 04     0.50413895E 04     0.58735485E 01      0.16956585E 01      0.16091301E-01
   0.29644549E 04    0.93363632E 04     0.61134351E 01    32.681840        32.801256        322.50334   17  3 16.937
   0.83019562E 04    0.16373517E 00     0.32875687E 02     0.19633645E 03      0.31055693E 03      0.13346355E 03
  STATION NO. =    42                   0.90367233E-01     0.14406625E-01      0.10638331E 00      0.19195909E-01
   0.51755409E 02    0.28782165E 03     0.34553865E 04    -0.17226279E 01      0.26338135E 03      0.33458256E 02

    4662.0           10    7  62      19   8    0.000     68880.000              209
   0.10669532E 04    0.64003710E 04    -0.37887166E 04    -0.75365083E 01     -0.54147414E 00     -0.99981956E 00
   0.11411132E 04    0.75138213E 04     0.76217970E 01   -30.280449       -30.422720        222.40976   20 11 47.821
   0.83030442E 04    0.16442782E 00     0.32875039E 02     0.19542344E 03      0.31106905E 03      0.31300290E 03
  STATION NO. =    35                  -0.19608287E 00     0.27718929E 01      0.39435557E 00     -0.72640847E-01
   0.83746319E 02    0.47095339E 02     0.11469581E 04    -0.67225178E 00      0.84847298E 02     -0.26572251E 02

END OF PROBLEM FOR ORBIT ESTIMATION
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V. LIST OF SYMBOLS

THE FOLLOWING IS A LIST OF SYMBOLS.THE METRIC SYSTEM OF UNITS IS USED IN THE PROGRAM--KILOGRAMS,KILOMETERS,METERS AND SECONDS. ALL ANGULAR QUANTITIES ARE IN RADIANS DURING THE COMPUTATIONAL PROCESS AND THEY ARE INPUT OR OUTPUT IN DEGREES OR SECONDS OF ARC.THE CONVENTIONS USED IN THE DEFINITIONS ARE

1) INTERMEDIATE VARIABLE--THE VALUE OF AN EQUATION(OR PART OF AN EQUATION) USED FOR INTERMEDIATE CALCULATION.

2) ASSIGNED VARIABLE--THE VARIABLE HAS SEVERAL DEFINITIONS.IT IS PROPERLY DEFINED IN THE MAIN PROGRAMS OR SUBROUTINES WHERE IT IS USED.

3) SEE INPUT LISTING--INPUT VARIABLE DEFINED IN THE INPUT LISTING.

4) MODIFIED JULIAN DATE--THE NUMBER OF INTEGRAL DAYS SINCE JANUARY 1, 1950 (0^hUT).

5) EQUA--EQUATION. IF NO REFERENCE IS GIVEN,THE EQUATION WILL BE FOUND IN THIS REPORT.

6) REF--REFERENCE.

VARIABLE	EQUA	REF	DEFINITION
A(1)			=1.0,HIGHER ORDER TERMS OF THE EARTH'S GRAVITATIONAL POTENTIAL FUNCTION ARE INCLUDED IN THE MATHEMATICAL MODEL. =0.0, NOT INCLUDED
A(2-7)	A.33-A.36		INTERMEDIATE VARIABLE
A1			INTERMEDIATE VARIABLE
A1M1	5	2	INTERMEDIATE VARIABLE
A1P1	5	2	INTERMEDIATE VARIABLE
A5	4	2	INTERMEDIATE VARIABLE
AELIP	A.28		INTERMEDIATE VARIABLE
AH			INTERMEDIATE VARIABLE
ALP			INTERMEDIATE VARIABLE
ALT(I) I=1,...,NMS	5-7	1	SEE INPUT LISTING. THE PROGRAM CONVERTS ALT(I) TO EARTH RADII.
ALTI			ASSIGNED VARIABLE
ALTIO	A.58		SATELLITE ALTITUDE (KM),OUTPUT
ANGDAT(111)			STORAGE ARRAY FOR COMPUTED STATION OBSERVATION DATA
ARG	27	1	REFRACTION CORRECTION FACTOR FOR RANGE RATE
ASCNOD	A.38		RIGHT ASCENSION OF THE ASCENDING NODE(DEG), OUTPUT
ASTIME	A.54		INTERMEDIATE VARIABLE
AXIMAJ	A.32		SEMI-MAJOR AXIS (KM),OUTPUT
AXSEMI			SEE INPUT LISTING
AZIMUT	151	1	AZIMUTH (DEG),OUTPUT

VARIABLE	EQUA	REF	DEFINITION
AZRATE	135	1	AZIMUTH RATE (DEG/SEC),OUTPUT
B	4	2	-.78539816 RADIANS
B1	5	2	INTERMEDIATE VARIABLE
B3	5	2	INTERMEDIATE VARIABLE
BELIP	A.29		INTERMEDIATE VARIABLE
BJK(1-3)			STORAGE CELLS
BLANKS			THE OCTAL NUMBER 606060606060
BLOCK(6,200)			STORAGE CELLS FOR X,Y,Z,$\dot{X}$,$\dot{Y}$,$\dot{Z}$ (FOR 200 CONSECUTIVE PRINT TIMES)
BN	A.23A		INTERMEDIATE VARIABLE
BNO	A.22		APPROXIMATION TO THE NUMBER OF REVOLUTIONS SINCE THE FIRST EQUATORIAL CROSSING
BN1	A.23B		INTERMEDIATE VARIABLE
BOX(5,9)	A.16A		STORAGE CELLS
C	5	2	$(\text{COSINE(ETA)})^{2.5}$
C1	5	2	INTERMEDIATE VARIABLE
C2	5	2	INTERMEDIATE VARIABLE
CDRAG	170A-170C	1	SEE INPUT LISTING
CELIP	A.30		INTERMEDIATE VARIABLE
COASC	A.56		INTERMEDIATE VARIABLE
COET	A.54		INTERMEDIATE VARIABLE
COINCL	A.56		INTERMEDIATE VARIABLE
CON(1-3)			ASSIGNED VARIABLES

VARIABLE	EQUA	REF	DEFINITION
CON(4-5)	122-139	1	INTERMEDIATE VARIABLES
CON(6-7)	17	1	INTERMEDIATE VARIABLES
CON(8)			ASSIGNED VARIABLE
CON(9-10)	141, 147	1	INTERMEDIATE VARIABLES
COPERI	A.56		INTERMEDIATE VARIABLE
COSALP	101	1	INTERMEDIATE VARIABLE
COSEN	A.18A		INTERMEDIATE VARIABLE
COTAU2	5	2	INTERMEDIATE VARIABLE
CSASI	98A,98B	1	INTERMEDIATE VARIABLE
CT(9)			SEE INPUT LISTING (THESE ARE RECOMPUTED AND PRINTED OUT AT THE END OF EACH FILTERING PHASE. SEE EQUATION A.16D)
CTAU	5	2	$(\mathrm{COSINE(TAU/2)})^{2.5}$
CTIN(6)	A.16D A.16C		3.0,4.0,6.0,8.0,11.0 AND .95
CTNEW(9)	A.14		INTERMEDIATE VARIABLES
DATES(3)			STORAGE CELLS
DATSEC(I) I=1,2			DJUPRT(I)*86400.0 + TIMSEC(I). TIME IN SECONDS CORRESPONDING TO INITIAL AND FINAL PRINT TIMES
DAYFLR			MODIFIED JULIAN DATE OF THE OBSERVATION TIME (USED DURING THE EPHEMERIS COMPUTATION)
DAYJL			MODIFIED JULIAN DATE OF THE EPHEMERIS PRINT TIME,OUTPUT

VARIABLE	EQUA	REF	DEFINITION
DAYREF			MODIFIED JULIAN DATE OF RIGHT ASCENSION AND DECLINATION OF SUN
DAYS			DAY OF YEAR ON OBSERVATION CARD
DCRATE			DECLINATION RATE (DEG/SEC), OUTPUT
DECLIN	127	1	DECLINATION (DEG),OUTPUT
DELAT(I) I=1,...,NMS	19	1	GEODETIC LATITUDE - GEOCENTRIC LATITUDE (FOR EACH STATION)
DELRT			REFRACTION CORRECTION FOR RANGE
DELS	25	1	REFRACTION CORRECTION FOR ELEVATION
DELTAM	A.20		INTERMEDIATE VARIABLE
DELTOR(6)			CORRECTION TOLERANCES FOR $X,Y,Z,\dot{X},\dot{Y},\dot{Z}$. THESE SIX VARIABLES ARE EQUAL TO 10.0,10.0, 10.0,0.01,0.01,0.01,RESPECTIVELY
DENL(3)			ARRAY OF INTERMEDIATE VARIABLES
DENTEM			DENSITY IN G/CM**3
DIAG(6,6)			ASSIGNED VARIABLES
DIFR(7)	49	1	DIFFERENCES BETWEEN MEASURED AND COMPUTED OBSERVATIONS,OUTPUT. THESE SEVEN CELLS REPRESENT - ELEVATION OR DECLINATION,AZIMUTH OR RIGHT ASCENSION,RANGE, RANGE RATE,ELEVATION RATE,AZIMUTH RATE AND RANGE ACCELERATION,RESPECTIVELY
DJ0			MODIFIED JULIAN DATE OF JANUARY 1,MOBS(2)-- WHERE MOBS(2) IS THE YEAR OF THE OBSERVATION
DJBGN			STORAGE CELL
DJREF			CURRENT EPOCH OF THE BASIC(SIDEREAL) SYSTEM
DJREG			MODIFIED JULIAN DATE CORRESPONDING TO THE RE-GULAR PRINT TIME

VARIABLE	EQUA	REF	DEFINITION
DJULN			CURRENT MODIFIED JULIAN DATE
DJULO			PREVIOUS MODIFIED JULIAN DATE
DJUPRT(2)			MODIFIED JULIAN DATES OF INITIAL AND FINAL PRINT TIMES
DLOG			INTERMEDIATE VARIABLE
DNP(37,89)			TABLE OF COMMON LOGARITHMS OF DENSITY (G/CM^3) AS A FUNCTION OF EXOSPHERIC TEMPERATURE AND ALTITUDE
DPRINS			EQUIVALENT TO DPRINT
DPRINT			SEE INPUT LISTING
DPRR			INTERMEDIATE VARIABLE
DSAVE(3)			VALUE OF THE UPDATED VELOCITY VECTOR ($\dot{X},\dot{Y},\dot{Z}$)
DSPI(I) I=1,...,NOSPRI			MODIFIED JULIAN DATES OF THE SPECIAL PRINT TIMES
DSTEP	102	1	POSITION PERTURBATION =.4(KM),IN STATE TRANSITION MATRIX
DTH1	194	1	INTERMEDIATE VARIABLE
DUM(3)			INTERMEDIATE VARIABLES
DV(3)			POSITION VECTOR X,Y,Z (KM)
DVEQ(12)			DVEQ(1),DVEQ(3),DVEQ(5) ARE EQUIVALENT TO DV(1),DV(2),DV(3),RESPECTIVELY. DVEQ(7),DVEQ(9),DVEQ(11) ARE EQUIVALENT TO DVP(1),DVP(2),DVP(3),RESPECTIVELY
DVH(3)			FINAL INTEGRATED VALUES OF X,Y,Z IN INTEGRATION SUBROUTINE
DVH2(3)			INTERMEDIATE VALUES OF X,Y,Z IN INTEGRATION SUBROUTINE

VARIABLE	EQUA	REF	DEFINITION
DVH2P(3)			INTERMEDIATE VALUES OF $\dot{X},\dot{Y},\dot{Z}$ IN INTEGRATION SUBROUTINE
DVHP(3)			FINAL INTEGRATED VALUES OF $\dot{X},\dot{Y},\dot{Z}$ IN INTEGRATION SUBROUTINE
DVHPP(3)			INTERMEDIATE VALUES OF $\ddot{X},\ddot{Y},\ddot{Z}$ IN INTEGRATION SUBROUTINE
DVO(3)			INITIAL VALUES OF X,Y,Z AT START OF INTEGRATION SUBROUTINE
DVP(3)			VELOCITY VECTOR $\dot{X},\dot{Y},\dot{Z}$ (KM/SEC)
DVPO(3)			INITIAL VALUES OF $\dot{X},\dot{Y},\dot{Z}$ AT START OF INTEGRATION SUBROUTINE
DVPOO(3)			INTERMEDIATE VALUES OF $\dot{X},\dot{Y},\dot{Z}$ IN INTEGRATION SUBROUTINE
DVPP(3)			INTERMEDIATE VALUES OF $\ddot{X},\ddot{Y},\ddot{Z}$ IN INTEGRATION SUBROUTINE
ECA	91A-97B	1	ECCENTRIC ANOMALY E1 OR E2
ECAD	91A-97B	1	ECCENTRIC ANOMALY E1 OR E2
ECANOM	A.42	1	ECCENTRIC ANOMALY USED DURING EPHEMERIS COMPUTATION
ECC	87	1	ECCENTRICITY,E
ECC2			ECC*ECC
ECCEN			SEE INPUT LISTING
ECCENT	A.31		ECCENTRICITY,OUTPUT
EELIP	A.31		COMPUTED ECCENTRICITY AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS
EELIP2			EELIP*EELIP
EHM			ALTITUDE ABOVE WHICH DENSITY IS COMPUTED BY EXPONENTIAL EXTRAPOLATION = 1000.0 KM

VARIABLE	EQUA	REF	DEFINITION
ELEMAX			SEE INPUT LISTING
ELEMIN			SEE INPUT LISTING
ELEVAT	120	1	ELEVATION (DEG),OUTPUT
ELRATE	134	1	ELEVATION RATE (DEG/SEC),OUTPUT
ENDDAT			BCD WORD -ENDDAT (SEE INPUT LISTING)
EPS	179	1	MEAN OBLIQUITY OF ECLIPTIC
ERASD(10)			ASSIGNED VARIABLES
ERASE(20)			ASSIGNED VARIABLES
ET			COMPUTED ECCENTRIC ANOMALY AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS
ETA(6)	24-26		INTERMEDIATE VARIABLES
ETASUN	177B	1	DIRECTION COSINE OF SUN
ETM			EXOSPHERIC TEMPERATURE BELOW WHICH DENSITY IS COMPUTED BY EXTRAPOLATION = 600.0 DEG K
EXTRIM			INCREMENT OF EXOSPHERIC TEMPERATURE BELOW LOWEST TEMPERATURE OF DNP DATA ALLOWED FOR LO[illegible] TEMPERATURE BRANCH = 100.0 DEG K
F	6	1	SEE INPUT LISTING
F1(6)	158-159	1	INTERMEDIATE VARIABLES
FCA	92,94	1	INTERMEDIATE VARIABLE
FCONST	170A-170C	1	INTERMEDIATE VARIABLE
FEARTH	6	1	$(1.0 - F)^2$, F_E
FILDIR(2)			BCD INFORMATION USED FOR HEADING OF EACH PAGE

VARIABLE	EQUA	REF	DEFINITION
FL0			0.0
FL1			1.0
FL10			10.0
FL12			12.0
FL1P5			1.5
FL2			2.0
FL24			24.0
FL2PI			2.0*PI
FL3			3.0
FL3600			3600.0,NUMBER OF SECONDS IN ONE HOUR
FL3652			36525.0,NUMBER OF DAYS IN A JULIAN CENTURY
FL4			4.0
FL5			5.0
FL6			6.0
FL60			60.0,NUMBER OF SECONDS IN ONE MINUTE
FL7			7.0
FL8			8.0
FL864H			86400.0,NUMBER OF SECONDS IN A DAY
FL9			9.0
FL96			96.0
FLP001			0.001
FLP01			0.01
FLP1			0.1

VARIABLE	EQUA	REF	DEFINITION
FLP5			0.5
FLPI			PI,3.14159265
FLRAD			.0174532925,CONVERSION FACTOR DEGREES TO RADIANS
FSM1	158	1	INTERMEDIATE VARIABLE
FSM2	159	1	INTERMEDIATE VARIABLE
G	4	2	.78539816 RADIANS (UNUSED)
GAM	178	1	LONGITUDE OF SUN
GAMS	24	1	TOTAL REFRACTION BENDING THROUGH THE TRO-POSPHERE (RADIANS)
GEOCEN	A.57		GEOCENTRIC LATITUDE (DEG),OUTPUT
GEODET	A.61		GEODETIC LATITUDE (DEG),OUTPUT
H(NMTP,6)	122-148	1	H MATRIX,THE MATRIX OF THE PARTIAL DERIVA-TIVES WITH RESPECT TO THE SIX ORBITAL ELEMENTS IN THE FORM OF POSITION AND VELOCITY COORDINATES
HCOEFF	4	2	INTERMEDIATE VARIABLE
HCOR(6)	23	1	INCREMENT LAYERS USED IN REFRACTION COR-RECTION SUBROUTINE
HDRAS	4	2	DIFFERENCE OF RASAT - SUNRA
HIND	192	1	VARIABLE INTEGRATION INTERVAL(SEC.)
HIND2			$(HIND)^2$
HIND26			$(HIND)^2/6.0$
HIND28			$(HIND)^2/8.0$

VARIABLE	EQUA	REF	DEFINITION
HIND29			$(HIND)^2/96.0$
HIND02			HIND/2.0
HIND06			HIND/6.0
HIND24			HIND/24.0
HNOW			ACCUMULATIVE INTEGRATION INTERVAL (THE LIMIT IS HTOTAL)
HPHTR(7,7)			ASSIGNED VARIABLES. MATRIX TO BE INVERTED OR ITS INVERSE.
HRPRT(2)			SEE INPUT LISTING
HTOFLR			INTEGRATION INTERVAL BETWEEN TWO OBSERVATION TIMES(SEC.)
HTOT1	95	1	INTERMEDIATE VARIABLE
HTOTAL			INTEGRATION INTERVAL BETWEEN TWO PRINT TIMES OR BETWEEN TWO OBSERVATION TIMES(SEC.)
HTOTAS			EQUIVALENT TO HTOTAL
HTR(6,NNTP)	50 50	1 1	THE WEIGHTING MATRIX OR THE TRANSPOSE OF H
I			PROGRAM INDEX
I12345			PROGRAM LOGIC CONTROL
IAM			INTERMEDIATE VARIABLE
IB(7)			STORAGE CELLS

VARIABLE	EQUA	REF	DEFINITION
ICOUNT			ASSIGNED VARIABLE
ICT			ITERATION COUNTER
IDIR			=1, FILTER IN BACKWARD DIRECTION =0, FILTER IN FORWARD DIRECTION
IEQUAL			PROGRAM LOGIC CONTROL
IEX			EXPONENT OF RANGE ON AN OBSERVATION CARD
IFF(7)			PROGRAM INDICES AND STORAGE CELLS
IFILSV			PREVIOUS VALUE OF IFILTR
IFILTR			=1, DJULN AND TNORMN CORRESPOND TO AN EPHE- MERIS PRINT TIME =0, DJULN AND TNORMN CORRESPOND TO AN OBS- ERVATION TIME =-1,DJULN AND TNORMN CORRESPOND TO AN EPHE- MERIS AND AN OBSERVATION TIME
IFINIS			=1,FINAL EPHEMERIS PRINT OUT =0,EPHEMERIS PRINT OUT TO CONTINUE
IFIRST			=0,1 FILTER ONLY =2, FILTER AND PRINT EPHEMERIS
IG(7)			PROGRAM INDICES AND STORAGE CELLS
IGO			=-1,TRANSFORMATION OF COVARIANCE MATRIX RESULTED IN NEGATIVE DIAGONAL ELEMENTS. PROGRAM WILL NOT CONTINUE. =0,1 TRANSFORMATION WAS SUCCESSFUL (SEE EQUATION 51, REFERENCE 1)
II			PROGRAM INDEX
IIN			SYSTEM INPUT TAPE
IJ			NUMBER OF STATIONS IN A BINARY DATA RECORD OBSERVING THE SATELLITE(IJ ≤ 10)

VARIABLE	EQUA	REF	DEFINITION
IJFILP			=1 ,INCREMENT JFILP BY 1,I.E.FILTER FORWARD =-1,INCREMENT JFILP BY -1,I.E.FILTER BACKWARD
IJKL			STORAGE CELL, EQUALS IOUT OR MBCD (SEE IOUT AND MBCD)
IL			=1,EPHEMERIS PRINT-OUT IS AT A SPECIAL PRINT TIME =0,EPHEMERIS PRINT-OUT IS AT A REGULAR PRINT TIME
ILIMIT			=0,DIFR ARE WITHIN THE TOLERANCES =1,DIFR ARE NOT WITHIN THE TOLERANCES (SEE DIFR)
ILMTO			VALUE OF ILIMIT AT THE FINAL OBSERVATION CARD
INCHM			INTEGRAL VALUE OF XINCHM (INTEGER)
INCTM			INTEGRAL VALUE OF XINCTM (INTEGER)
INTEND			=-1,INTEGRATION IS COMPLETE =0, INTEGRATION IS NOT COMPLETE
IONE			=0,REWIND TAPE MBCD =1,DO NOT REWIND TAPE MBCD
IOUT			SYSTEM OUTPUT TAPE
IPAGE			PAGE COUNTER FOR FILTERING OUTPUT
IPHI			PROGRAM INDEX
IREC			PROGRAM INDEX
IREV			REVOLUTION NUMBER,OUTPUT
IREVO			SEE INPUT LISTING
IREWD			=0,REWIND TAPE MBIN =1,DO NOT REWIND TAPE MBIN
ISAVE			PROGRAM INDEX

VARIABLE	EQUA	REF	DEFINITION
ISCLH			INTEGRAL VALUE OF XISCLH / XINCHM (INTEGER)
ISH			INTEGRAL VALUE OF SHM (INTEGER)
ISMOOH			SEE INPUT LISTING
IST			INTEGRAL VALUE OF STM (INTEGER)
ITCT			ITERATION COUNTER
ITIME			STORAGE CELL
ITYPE			=1,FINAL DATA RECORD AT AN EPHEMERIS PRINT TIME =-1,ANOTHER DATA RECORD TO FOLLOW AT AN EPHEMERIS PRINT TIME
J			PROGRAM INDEX
JACK			=0,STORE PROGRAM CONSTANTS =1,CALCULATE INITIAL VALUES
JB			PROGRAM INDEX
JDAPRT(2)			SEE INPUT LISTING
JERR			PROGRAM LOGIC CONTROL
JFILP			OBSERVATION CARD COUNTER
JFIRST			=0,READ OBSERVATION CARDS IN INCREASING ORDER AND FILTER =1,READ OBSERVATION CARDS IN DECREASING ORDER AND FILTER =2,READ OBSERVATION CARDS IN INCREASING ORDER ,FILTER AND PRINT EPHEMERIS
JJ			PROGRAM INDEX
JM			PROGRAM INDEX
JMOPRT(2)			SEE INPUT LISTING

VARIABLE	EQUA	REF	DEFINITION
JSP			PROGRAM COUNTER FOR SPECIAL PRINT TIMES
JSPDA			SEE INPUT LISTING
JSPMO			SEE INPUT LISTING
JSPSAV			VALUE OF JSP AT THE PREVIOUS OBSERVATION TIME
JSPYR			SEE INPUT LISTING
JTYPRT			SEE INPUT LISTING
JYRPRT(2)			SEE INPUT LISTING
K			PROGRAM INDEX
KARG			PROGRAM LOGIC CONTROL
KARGSV			VALUE OF KARG AT THE OBSERVATION TIME
KBEG			PROGRAM INDEX
KCLASS			SATELLITE CLASSIFICATION ON OBSERVATION CARD
KCOUNT			SEE INPUT LISTING
KDAOUT			CALENDAR DAY,OUTPUT
KDECOB			DECADE OF TIME IN YEARS(50,60,70,...)
KEY			PROGRAM INDEX
KEYTAP			SEE INPUT LISTING
KF0			0
KF1			1
KF10			10
KF100			100
KF2			2

VARIABLE	EQUA REF	DEFINITION
KF25		25
KF3		3
KF31		31
KF4		4
KF5		5
KF6		6
KF60		60
KF7		7
KF8		8
KF9		9
KFILPR		=0,PROGRAM IS FILTERING AND COMPUTING EPHEMERIS =1,PROGRAM IS COMPUTING ONLY THE EPHEMERIS
KFILPT		=0,PROGRAM IS FILTERING =1,PROGRAM IS FILTERING AND COMPUTING EPHEMERIS
KFIN		PROGRAM INDEX
KHROUT		HOUR OF DAY,OUTPUT
KITER		=1,OBSERVATION CARD HAS BEEN SAVED FOR SMOOTHING =0,OBSERVATION CARD HAS NOT BEEN SAVED FOR SMOOTHING
KLAMRA		PROGRAM LOGIC CONTROL
KLONOS		PROGRAM INDEX
KMIOUT		MINUTE OF HOUR,OUTPUT
KMOOUT		CALENDAR MONTH,OUTPUT

VARIABLE	EQUA	REF	DEFINITION
KOBSPR			SEE INPUT LISTING
KONCE			=0,THE FIRST SIX (OR LESS) OBSERVATION CARDS HAVE BEEN SAVED FOR SMOOTHING =1,OBSERVATION CARDS,OTHER THAN THE FIRST SIX HAVE BEEN SAVED FOR SMOOTHING
KQ			PROGRAM INDEX
KQ20			INTERMEDIATE VARIABLE
KTOT			PROGRAM INDEX
KTOTM1			PROGRAM INDEX
KTYPRT			(SEE JTYPRT)
KYROUT			CALENDAR YEAR,OUTPUT (LAST 2 DIGITS OF 19XX)
L(7)			PROGRAM INDICES AND STORAGE CELLS
LASTCA			LAST VALUE OF JFILP AT WHICH AN OBSERVATION CARD HAS BEEN ACCEPTED
LFO			LINE COUNTER INCREMENT
LINES			LINE COUNTER FOR FILTERING OUTPUT
LINOUT			LINE COUNTER FOR EPHEMERIS OUTPUT
LMBDA			PROGRAM INDEX
LOOKAN			PROGRAM LOGIC CONTROL FOR EPHEMERIS OUTPUT
LPAGE			PAGE COUNTER FOR EPHEMERIS OUTPUT
LUP			PROGRAM INDEX
LUV			PROGRAM INDEX
LUV1			PROGRAM INDEX
MBCD			BCD OUTPUT TAPE REQUESTED BY CUSTOMER

VARIABLE	EQUA	REF	DEFINITION
MBIN			BINARY OUTPUT TAPE REQUESTED BY CUSTOMER
MEQ(J) J=1,...,9			=0,COMPUTE TRANSFORMATION MATRIX TO THE MEAN EQUINOX AND EQUATOR OF THE CELESTIAL REFERENCE SYSTEM =1,TRANSFORMATION MATRIX HAS BEEN COMPUTED (SEE PPRIME(3,3,J)
MERASE(20)			ASSIGNED VARIABLES
MMTAPE			STORAGE TAPE USED BY PROGRAM
MOBS(1)			SATELLITE NUMBER ON OBSERVATION CARD
MOBS(2-4)			SEE INPUT LISTING OR YEAR,MONTH,DAY OF OBSERVATION
MOLD			STORAGE CELL
MSTHR			HOUR OF GREENWICH MEAN SIDEREAL TIME,OUTPUT
MSTMIN			MINUTE OF GREENWICH MEAN SIDEREAL TIME, OUTPUT
N			PROGRAM INDEX
N2	A.23C		INTEGRAL VALUE OF BN
N3	A.23D		INTEGRAL VALUE OF BNO
NAT			SEE INPUT LISTING
NCARSV			TOTAL NUMBER OF OBSERVATION CARDS
NCOL			COLUMN ERROR DESIGNATOR
ND1	20	1	=2,THE MATRIX P1TR(SEE P1TR) HAS BEEN RECOMPUTED,HENCE PN1 MUST BE RECOMPUTED =1,P1TR MATRIX HAS NOT BEEN RECOMPUTED
ND1M			FORTRAN DIMENSION OF A SQUARE MATRIX

VARIABLE	EQUA	REF	DEFINITION
NDIR			=1,FILTER AND COMPUTE EPHEMERIS =2,COMPUTE EPHEMERIS,NO FILTERING =3,COMPUTE EPHEMERIS,NO FILTERING.SET NDIR=1
NE2			YEAR OF OBSERVATION
NEQ			CODE OF THE CELESTIAL REFERENCE SYSTEM ON THE OBSERVATION CARD
NEQ1			STORAGE CELL FOR NEQ
NF			PROGRAM INDEX
NFIRST			INITIALIZATION SECTION CONTROL (INTEGER)
NG			PROGRAM INDEX
NHM			NO. OF ALTITUDES IN DNP TABLE = 89 (INTEGER)
NHMSCL			INDEX FOR HIGH ALTITUDE BRANCH
NMS			SEE INPUT LISTING
NNEQ			PROGRAM INDEX
NNTP			IF NTP =1,NNTP =2 IF NTP =1, NNTP =NTP NNTP REPRESENTS THE NUMBER OF SIMULTANEOUS OBSERVATIONS ON AN OBSERVATION CARD. NNTP IS ALSO USED AS THE DIMENSION OF A MATRIX TO BE INVERTED(SEE HPHTR)
NO			STORAGE CELL
NOB			SEE INPUT LISTING
NOSAT			SEE INPUT LISTING
NOSPRI			SEE INPUT LISTING. NOSPRI IS DECREASED BY 1 EACH TIME THE PROGRAM PRINTS AT A SPECIAL PRINT TIME

VARIABLE	EQUA	REF	DEFINITION
NOSPRS			VALUE OF NOSPRI AT THE PREVIOUS OBSERVATION TIME
NRE			=1,INITIALIZE PROGRAM LOGIC FOR COMPUTATION OF DECLINATION AND RIGHT ASCENSION =2,INITIALIZATION HAS BEEN DONE
NS			PROGRAM INDEX
NSG(I) I=1,...,NMS	16,17	1	SEE INPUT LISTING
NSTPRT			SEE INPUT LISTING
NTIME			STORAGE CELL
NTM			NO. OF TEMPERATURES IN DNP TABLE = 37 (INTEGER)
NTP			CODE WHICH DESIGNATES TYPE OF SIMULTANEOUS OBSERVATIONS =1,DECLINATION,RIGHT ASCENSION =2 ELEVATION,AZIMUTH =3,ELEVATION,AZIMUTH,RANGE =4,ELEVATION,AZIMUTH,RANGE,RANGE RATE =7,SAME AS =4 AND ELEVATION RATE,AZIMUTH RATE, RANGE ACCELERATION
NTPOLD			STORAGE CELL,VALUE OF NTP
NUMBER(111)			EQUIVALENT TO ANGDAT(111)
NUMSTA(I) I=1,...,NMS			SEE INPUT LISTING
NWORDS			PROGRAM INDEX
OBSC(7)	120- 141		COMPUTED OBSERVATIONS.THESE SEVEN VARIABLES REFER TO ELEVATION OR DECLINATION,AZIMUTH OR RIGHT ASCENSION,RANGE,RANGE RATE,ELEVATION RATE,AZIMUTH RATE AND RANGE ACCELERATION,RES-PECTIVELY.
OBSM(7)			MEASURED(INPUT) OBSERVATIONS ON THE OBSER-VATION CARD.THESE SEVEN VARIABLES ARE ANALO-GOUS TO OBSC(7).

VARIABLE	EQUA	REF	DEFINITION
OBSNO			COLUMNS 73-78 OF OBSERVATION CARD
OINCL			SEE INPUT LISTING
OINCLI	A.37		INCLINATION (DEG),OUTPUT
OKINT1	193	1	INTERMEDIATE VARIABLE
OLAMO	A.64		SATELLITE LONGITUDE (DEG),OUTPUT
OLAMS	A.64		SATELLITE LONGITUDE (RAD)
OLAMSP	A.64		SATELLITE LONGITUDE (RAD)
OLDDAY			VALUE OF MODIFIED JULIAN DATE(DJULN) AT WHICH AN OBSERVATION CARD HAS BEEN ACCEPTED
OLDTIM			VALUE OF TNORMN CORRESPONDING TO DJULN (SEE OLDDAY)
OMEANA	A.43		MEAN ANOMALY (DEG),OUTPUT
OMS	180	1	INTERMEDIATE VARIABLE
OMSAT			SEE INPUT LISTING
OMU			SEE INPUT LISTING,μ
ONE			1.0
ONUM			INTERMEDIATE VARIABLE
P	4	2	.20943951 RADIANS
P0			INTERMEDIATE VARIABLE
P12(3,3)			ASSIGNED VARIABLES
P1TR(3,3)	15,20	1	TRANSPOSE OF NUTATION-PRECESSION MATRIX
P2(3,3)			ASSIGNED VARIABLES
P2TR(3,3)	15	1	NUTATION-PRECESSION MATRIX (COMPUTED AT DJULN)

VARIABLE	EQUA	REF	DEFINITION
PASS			SEE INPUT LISTING
PERIGE	A.41		ARGUMENT OF PERIGE (DEG),OUTPUT
PERIOD			PERIOD OF SATELLITE AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS(SEC)
PERMUT(7)			STORAGE CELLS
PHI(6,6)	51,108	1	STATE TRANSITION MATRIX
PHII(7,7)	50	1	INTERMEDIATE MATRIX
PHILAT(I) I=1,...,NMS			SEE INPUT LISTING
PHITR(6,6)			ASSIGNED VARIABLES
PMAT(6,6)	50-52	1	COVARIANCE MATRIX
PN1(3,3)	20	1	TRANSFORMATION MATRIX FROM THE TRUE EQUINOX AND EQUATOR OF DATE TO THE MEAN EQUINOX AND EQUATOR OF THE PARTICULAR CELESTIAL SYSTEM
PN1TR(3,3)	129, 131	1	TRANSPOSE OF THE PN1 MATRIX
PNODAL	A.23		NODAL PERIOD OF SATELLITE AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS (SEC.)
PPRIME(3,3,J) J=1,...,9	20	1	TRANSFORMATION MATRICES TO THE MEAN EQUINOX AND EQUATOR OF THE CELESTIAL REFERENCE SYSTEM
Q(7)	53	1	SEE INPUT LISTING (THESE ARE RECOMPUTED AND PRINTED OUT AT THE END OF EACH FILTERING PHASE. SEE EQUATION A.15)
QP(2)	53	1	SEE INPUT LISTING (THESE ARE RECOMPUTED AND PRINTED OUT AT THE END OF EACH FILTERING PHASE SEE EQUATION A.15)
R	5	2	.3

VARIABLE	EQUA	REF	DEFINITION
R2	99	1	INTERMEDIATE VARIABLE
RADIUS			DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS
RADPRT	A.24		DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM),OUTPUT
RALON	18	1	RIGHT ASCENSION OF THE OBSERVING STATION
RANGES	140	1	RANGE (KM),OUTPUT
RANRAT	141	1	RANGE RATE (KM),OUTPUT
RARATE			RIGHT ASCENSION RATE (DEG/SEC),OUTPUT
RASAT			RIGHT ASCENSION OF SATELLITE (RADIANS)
RASE(6)	2		CORRECTION IN POSITION AND VELOCITY VECTOR AT THE LAST OBSERVATION CARD WHICH HAS BEEN ACCEPTED.THESE ARE COMPUTED WHENEVER THE PROGRAM ITERATES,OUTPUT
RDPP	170A-170C	1	INTERMEDIATE VARIABLE
REARTH	7	1	SEE INPUT LISTING,R_E
RER	158, 159	1	INTERMEDIATE VARIABLE
RER2	158, 159	1	INTERMEDIATE VARIABLE
RESULT			INTERMEDIATE VARIABLE
RFC(6)			INTERMEDIATE VARIABLES
RHI(7,7)	50, 52	1	INTERMEDIATE MATRIX
RHO	170A-170C	1	ATMOSPHERIC DENSITY (KG/M^3)

VARIABLE	EQUA	REF	DEFINITION
RMEAN			REARTH*(2.0-F)/2.0
RT2	128	1	INTERMEDIATE VARIABLE
RTASC	126	1	RIGHT ASCENSION (DEG),OUTPUT
RTC2	122,134-147	1	RANGE SQUARED
RX	128	1	INTERMEDIATE VARIABLE
RX2	129	1	INTERMEDIATE VARIABLE
S	5	2	$(SINE(THETA))^{2.5}$
SA1	80A	1	INTERMEDIATE VARIABLE
SA2	80B	1	INTERMEDIATE VARIABLE
SA3	80C	1	INTERMEDIATE VARIABLE
SAPA	88A	1	INTERMEDIATE VARIABLE
SATRAD			DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM)
SAVE(3)			VALUE OF THE UPDATED POSITION VECTOR (X,Y,Z)
SD	80A-80C	1	INTERMEDIATE VARIABLE
SDV(6,6)			VALUES OF POSITION AND VELOCITY VECTOR AT SIX OBSERVATION TIMES. THESE WILL BE USED FOR SMOOTHING.
SECOUT			SECONDS OF MINUTE,OUTPUT
SECPRT(2)			SEE INPUT LISTING
SHM			LOWEST ALTITUDE IN DNP TABLE = 120.0 KM
SIASC	A.56		INTERMEDIATE VARIABLE

VARIABLE	EQUA	REF	DEFINITION
SIET	A.54		INTERMEDIATE VARIABLE
SIGNA			=1.0,VALUE OF AN OBSERVATION INPUT IS POSITIVE =-1.0,VALUE OF AN OBSERVATION INPUT IS NEGATIVE
SIGXX(6)	A.1A- A.2C		ERRORS IN POSITION AND VELOCITY DUE TO A STANDARD TIMING ERROR
SIINCL	A.56		INTERMEDIATE VARIABLE
SINALP	101	1	INTERMEDIATE VARIABLE
SINE(6)	26	1	INTERMEDIATE VARIABLES
SINEN	A.18B		INTERMEDIATE VARIABLE
SIPA	88B	1	INTERMEDIATE VARIABLE
SIPERI	A.56		INTERMEDIATE VARIABLE
SLAT(I) I=1,...,NMS	6	1	GEOCENTRIC LATITUDE FOR EACH STATION
SLON(I) I=1,...,NMS	18	1	SEE INPUT LISTING
SMALLA	A.32		COMPUTED SEMI-MAJOR AXIS (KM)
SMATS(6,6)			VALUE OF PMAT(6,6) AT AN OBSERVATION WHICH HAS BEEN ACCEPTED
SMDAY(6)			VALUES OF DJULN CORRESPONDING TO THE STORED VALUES OF THE POSITION-VELOCITY VECTOR (SEE SDV(6,6))
SMTIM(6)			VALUES OF TNORMN CORRESPONDING TO SMDAY(6)
SOA	84	1	INTERMEDIATE VARIABLE
SOB	85	1	INTERMEDIATE VARIABLE
SOC	86	1	INTERMEDIATE VARIABLE

VARIABLE	EQUA	REF	DEFINITION
SOGA	A.58		INTERMEDIATE VARIABLE
SOGB	A.61		INTERMEDIATE VARIABLE
SOGBO	A.61		INTERMEDIATE VARIABLE
SOGC	A.60		INTERMEDIATE VARIABLE
SOK	90	1	INTERMEDIATE VARIABLE
SOKB	90	1	INTERMEDIATE VARIABLE
SOKC	93-96	1	INTERMEDIATE VARIABLE
SOKV	100A-100B	1	INTERMEDIATE VARIABLE
SOS	84	1	INTERMEDIATE VARIABLE
SPHR			SEE INPUT LISTING
SPMAT(6,6)			DIAGONAL ELEMENTS OF THE COVARIANCE MATRIX (PMAT) CORRESPONDING TO SDV (SEE SDV)
SPMI			SEE INPUT LISTING
SPSEC			SEE INPUT LISTING
SQTIME	A.54		INTERMEDIATE VARIABLE
SQTMUA	A.54		INTERMEDIATE VARIABLE
SQTOLR(7)	53	1	SQUARE ROOT OF DIAGONAL ELEMENTS IN R MATRIX THESE SEVEN VARIABLES REFER TO ELEVATION OR DECLINATION, AZIMUTH OR RIGHT ASCENSION, RANGE,RANGE RATE,ELEVATION RATE,AZIMUTH RATE OR RANGE ACCELERATION,RESPECTIVELY
SRAD(I) I=1,...,NMS	7	1	GEOGENTRIC RADIUS OF EACH STATION
SSAT			SEE INPUT LISTING

VARIABLE	EQUA	REF	DEFINITION
STEP2	101	1	DSTEP + DSTEP OR VSTEP + VSTEP
STM			HIGHEST TEMPERATURE IN DNP TABLE = 2400.0 DEG K
STOME	97A	1	INTERMEDIATE VARIABLE
STOU			INTERMEDIATE VARIABLE
STOUSQ	97B	1	INTERMEDIATE VARIABLE
STSECO			SECONDS OF GREENWICH MEAN SIDEREAL TIME,OUTPUT
SUM(9)	A.16B		TOTAL NUMBER OF EACH TYPE OF OBSERVATIONS. THESE REFER TO DECLINATION,RIGHT ASCENSION, ELEVATION,AZIMUTH,RANGE,RANGE RATE,ELEVATION RATE,AZIMUTH RATE AND RANGE ACCELERATION
SUNDEC			DECLINATION OF SUN
SUNRAS			RIGHT ASCENSION OF THE SUN
T	5	2	EXOSPHERIC TEMPERATURE (DEG K)
TABLE			INTERMEDIATE VARIABLE
TC	13	1	MODIFIED JULIAN DATE DIVIDED BY 36525.0
TEM1			DECLINATION OR ELEVATION (DEG) ON OBSERVATION CARD
TEMP			ASSIGNED VARIABLE
TEMPE			ASSIGNED VARIABLE
TEMTHD	90	1	INTERMEDIATE VARIABLE
TEMTHN	90	1	INTERMEDIATE VARIABLE
THET	90	1	INTERMEDIATE VARIABLE
TI			TC (SEE TC)
TI2			TC*TC (SEE TC)
TI3			TC*TC*TC (SEE TC)

VARIABLE	EQUA REF	DEFINITION
TIEQUI(I) I=1,...,9		YEARS OF STANDARD CELESTIAL REFERENCE SYSTEMS. TIEQUI(1) - YEAR OF DATE (ON THE OBSERVATION CARD) TIEQUI(2) - 1900.0 TIEQUI(3) - 1920.0 TIEQUI(4) - 1975.0 TIEQUI(5) - 2000.0 TIEQUI(6) - 1850.0 TIEQUI(7) - 1855.0 TIEQUI(8) - 1875.0 TIEQUI(9) - 1960.0 THE JULIAN DAYS CORRESPONDING TO THESE EPOCHS HAVE BEEN CONVERTED TO MODIFIED JULIAN DAYS AND DIVIDED BY 36525.0
TIMFLR		TIME OF DAY IN SECONDS CORRESPONDING TO DAYFLR
TIMREG		TIME OF DAY IN SECONDS CORRESPONDING TO DJREG
TIMSEC(2)		TIME OF DAY IN SECONDS CORRESPONDING TO THE INITIAL AND FINAL PRINT TIMES(SEE DJUPRT)
TIMSSS(1)		EQUIVALENT TO TIMSEC(1)
TIMTOL		SEE INPUT LISTING
TINI	A.22	DJULN*86400.0 + TNORMN. TIME IN SECONDS CORRESPONDING TO THE INPUT DATE AND TIME
TITLE(11)		SEE INPUT LISTING
TN2PHI	A.60	INTERMEDIATE VARIABLE
TNEXOS		SEE INPUT LISTING
TNO	A.21	TIME(SEC) TO THE FIRST EQUATORIAL CROSSING FROM THE TIME OF THE INPUT ORBITAL ELEMENTS
TNORMN		TIME OF DAY IN SECONDS CORRESPONDING TO DJULN
TNORMO		TIME OF DAY IN SECONDS CORRESPONDING TO DJULO

VARIABLE	EQUA	REF	DEFINITION
TNORNS			EQUIVALENT TO TNORMN
TNOROS			EQUIVALENT TO TNORMO
TOLER(7)			REJECTION TOLERENCES (DEG),OUTPUT
TOTSEO			OLDDAY * 86400.0 + OLDTIM. TIME IN SECONDS OF OBSERVATION LASTCA (SEE LASTCA) WHEN THE PROGRAM CALLS SUBROUTINE ORBINT FOR THE FIRST TIME.
TRIGE(6)	24-25	1	INTERMEDIATE VARIABLES
TSEC			STORAGE CELL
TSPI(I) I=1,...,NOSPRI			TIME OF DAY IN SECONDS CORRESPONDING TO DSPI
U			INTERMEDIATE VARIABLE
UMEAN1	92	1	INTERMEDIATE VARIABLE,MEAN ANOMALY
UMEAN2	94	1	INTERMEDIATE VARIABLE,MEAN ANOMALY
VN	A.17		INTERMEDIATE VARIABLE
VSQD	A.25		INTERMEDIATE VARIABLE
VSTEP	102	1	VELOCITY PERTURBATION =.01(KM/SEC),IN STATE TRANSITION MATRIX
VTOTPR	A.25		VELOCITY (KM/SEC),OUTPUT
WASC			SEE INPUT LISTING
WEARTH	17	1	RATE OF ROTATION OF THE EARTH (RAD/SEC),ω_E =.000072921150
WIBD(7,2)			BCD INFORMATION
WPERI			SEE INPUT LISTING
WX	168A	1	INTERMEDIATE VARIABLE

VARIABLE	EQUA	REF	DEFINITION
WXYZ	169	1	INTERMEDIATE VARIABLE
WY	168B	1	INTERMEDIATE VARIABLE
XBAR	89A, 97A	1	INTERMEDIATE VARIABLE
XIG(6,6)	107	1	INTERMEDIATE VARIABLES
XIMET			INTERMEDIATE VARIABLE
XINCHM			INCREMENT OF ALTITUDE IN DNP TABLE = 10.0 KM
XINCTM			INCREMENT OF TEMPERATURE IN DNP TABLE = -50.0 DEG K
XIPET			INTERMEDIATE VARIABLE
XISCLH			CONTANT USED TO COMPUTE POINTS TO BE USED FOR HIGH ALTITUDE EXPONENTIAL EXTRAPOLATION =50.0
XISUN	177A	1	DIRECTION COSINE OF SUN
XLDEN			INTERMEDIATE VARIABLE
XLST			EXOSPHERIC TEMPERATURE BELOW WHICH THE DENSITY WILL NOT BE COMPUTED = 500 DEG K
XM(3,3)			ASSIGNED VARIABLES
XMEAN	A.57		SEE INPUT LISTING
XMINDN			$.31623*10^{-19}$
XMIPRT(2)			SEE INPUT LISTING
XMN	A.19		INTERMEDIATE VARIABLE
XMN1			INTERMEDIATE VARIABLE
XMNTRU			INTERMEDIATE VARIABLE
XMTR(3,3)	122-139	1	TRANSPOSE OF THE XM MATRIX (SEE XM,DEFINED IN SUBROUTINE TRANSF)

RIABLE	EQUA	REF	DEFINITION
U			INTERMEDIATE VARIABLE
2(3,3)	14	1	NUTATION MATRIX
B			3.0,INTERVAL BETWEEN EPOCHS OF BASIC REFERENCE SYSTEM
U	84,103,105	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
UP	82,103,105	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
1	84	1	INTERMEDIATE VARIABLE (UNPERTURBED OR PERTURBED VALUE)
1P	82,84	1	INTERMEDIATE VARIABLE (UNPERTURBED OR PERTURBED VALUE)
2	98A	1	INTERMEDIATE VARIABLE
20	98A,103	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
2P	100A	1	INTERMEDIATE VARIABLE
2PO	100A ,105	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
K	A.24		INTERMEDIATE VARIABLE
KP	A.26		INTERMEDIATE VARIABLE
YWMU	A.28		INTERMEDIATE VARIABLE
SQRT			INTERMEDIATE VARIABLE
ZO(3)	15	1	SATELLITE COORDINATES IN CELESTIAL SYSTEM
ZS(3)	16	1	STATION COORDINATES
ZSO(3)	126-133	1	STATION COORDINATES IN CELESTIAL SYSTEM
ZT(3)	16	1	SATELLITE COORDINATES (X,Y,Z) IN A TOPOCENTRIC SYSTEM

VARIABLE	EQUA	REF	DEFINITION
XYZTP(3)	17	1	SATELLITE COORDINATES ($\dot{X}$,$\dot{Y}$,$\dot{Z}$) IN A TOPOCENTRIC SYSTEM
YBAR	89B,97B	1	INTERMEDIATE VARIABLE
YW0	83	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
YW0P	82,103-106	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
YW1P	82,84	1	INTERMEDIATE VARIABLE (UNPERTURBED OR PERTURBED VALUE)
YW2	98B	1	INTERMEDIATE VARIABLE
YW20	98B,103,104	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
YW2P	100B	1	INTERMEDIATE VARIABLE
YW2P0	100B,105-106	1	INTERMEDIATE VARIABLE (UNPERTURBED VALUE)
YWKP	A.27		INTERMEDIATE VARIABLE
ZDAT(3)			SEE INPUT LISTING OR HOUR,MINUTE,SECOND OF OBSERVATION
ZETSUN	177C	1	DIRECTION COSINE OF SUN
ZH			ALTITUDE OF SATELLITE (KM)
ZONHAR(5)	158,159	1	SEE INPUT LISTING
ZR1	158-159	1	INTERMEDIATE VARIABLE
ZR2	158-159	1	INTERMEDIATE VARIABLE
ZR3	158-159	1	INTERMEDIATE VARIABLE
ZR4	158-159	1	INTERMEDIATE VARIABLE
ZRDXT	134,136	1	INTERMEDIATE VARIABLE
ZSECD(3)	149A-149C	1	ACCELERATIONS $\ddot{X}$,$\ddot{Y}$,$\ddot{Z}$ (KM/SEC^2)

VI. FLOW CHARTS

A. MAIN PROGRAM LOGIC

MAIN2

THIS IS THE MAIN PROGRAM OF THE MAIN LINK.NOTE,THE PROGRAM IS CHAINED AND WRITIEN IN FORTRAN 4.

VARIABLE	EQUA REF	DEFINITION
MERASE(1)		=0,FIRST TIME THROUGH THE PROGRAM LOOP =1,MULTIPLE PROBLEM OR =1,ALL DATA HAS BEEN READ.NO DISABLING DATA ERRORS = -1, DATA INPUT ERROR.PROGRAM WILL GO TO NEXT PROBLEM

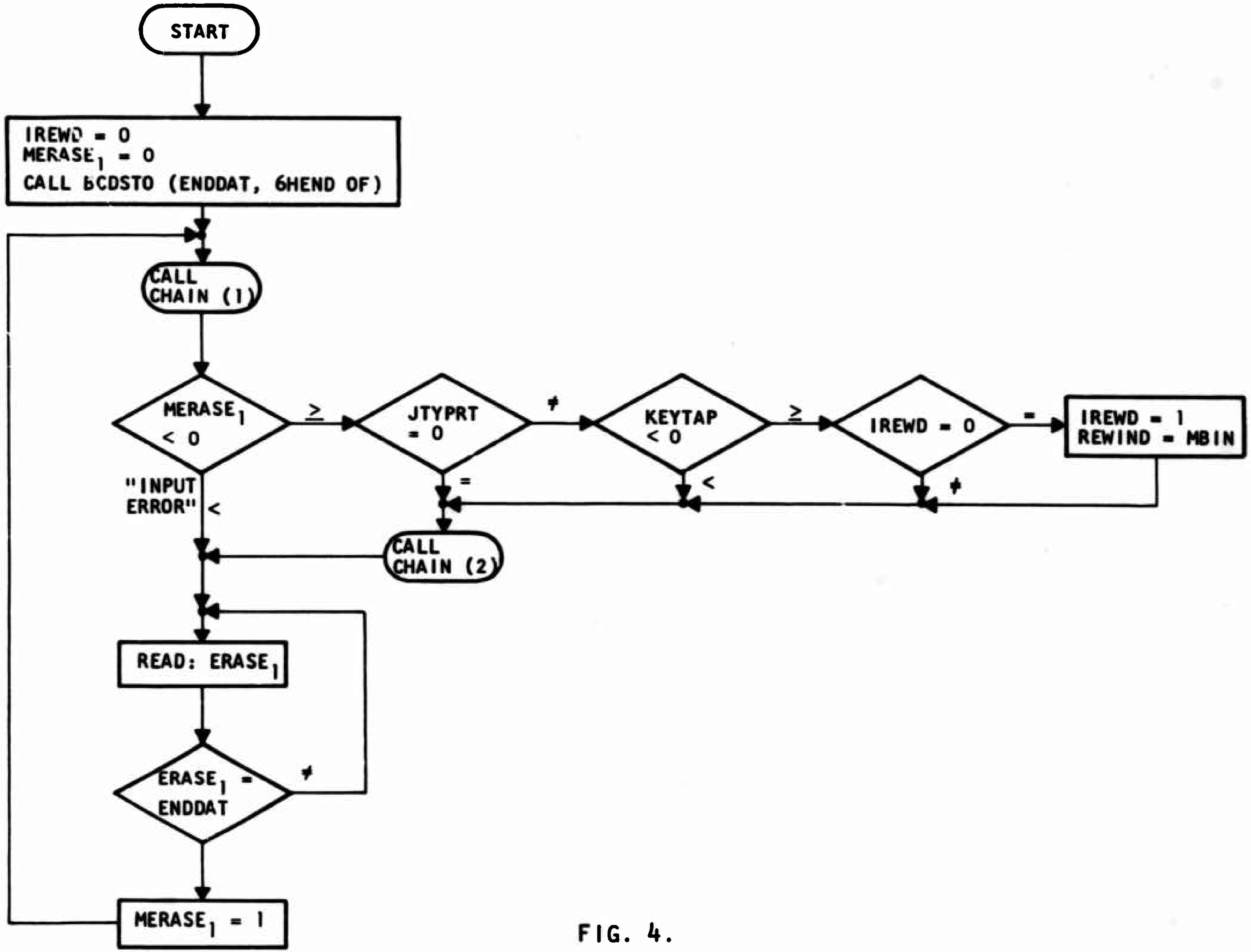
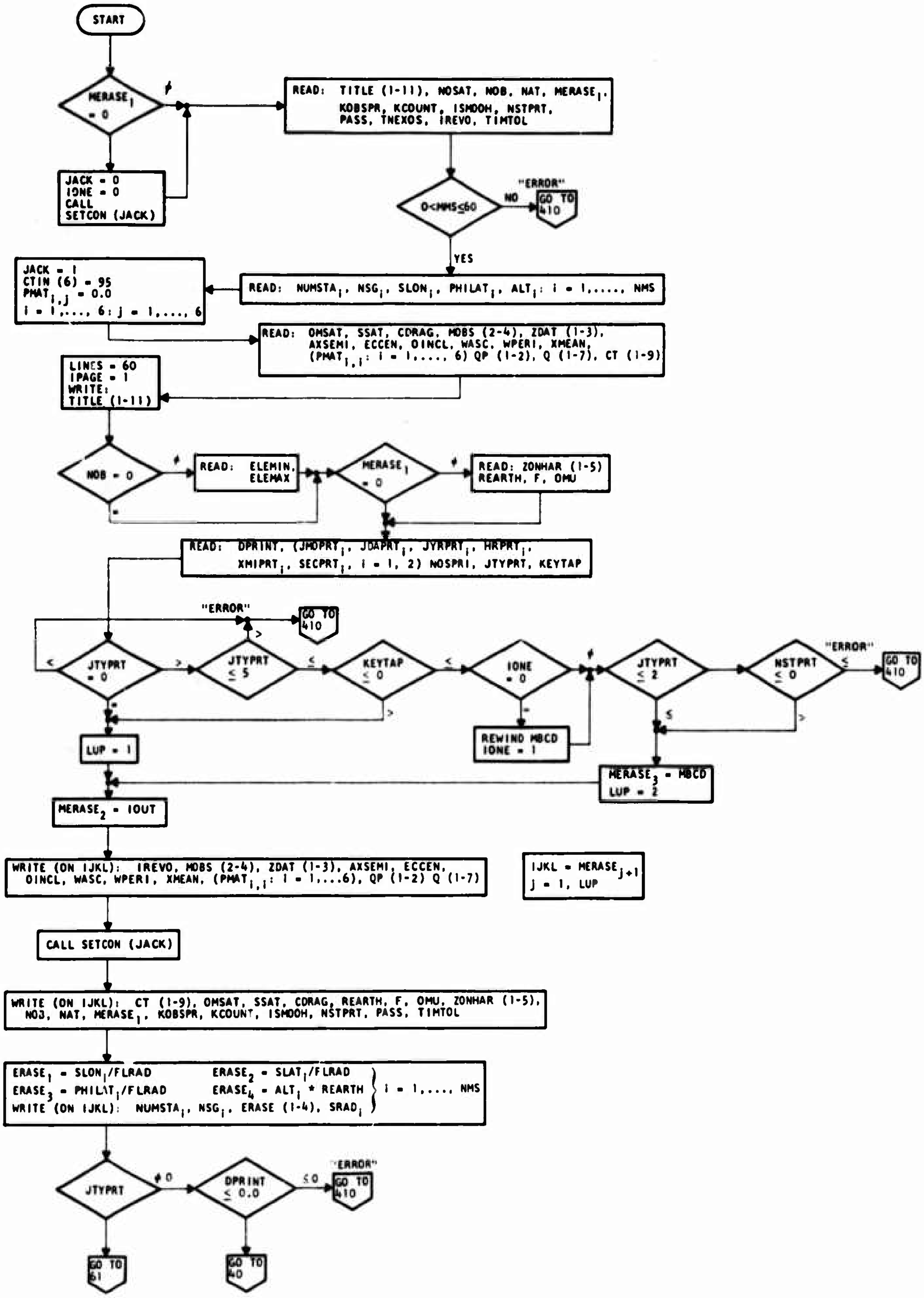

START
IREWD = 0
MERASE1 = 0
CALL BCDSTO (ENDDAT, 6HEND OF)
CALL CHAIN (1)
MERASE1 < 0
"INPUT ERROR"
JTYPRT = 0
KEYTAP < 0
IREWD = 0
IREWD = 1
REWIND = MBIN
CALL CHAIN (2)
READ: ERASE1
ERASE1 = ENDDAT
MERASE1 = 1

FIG. 4.

AFILT2

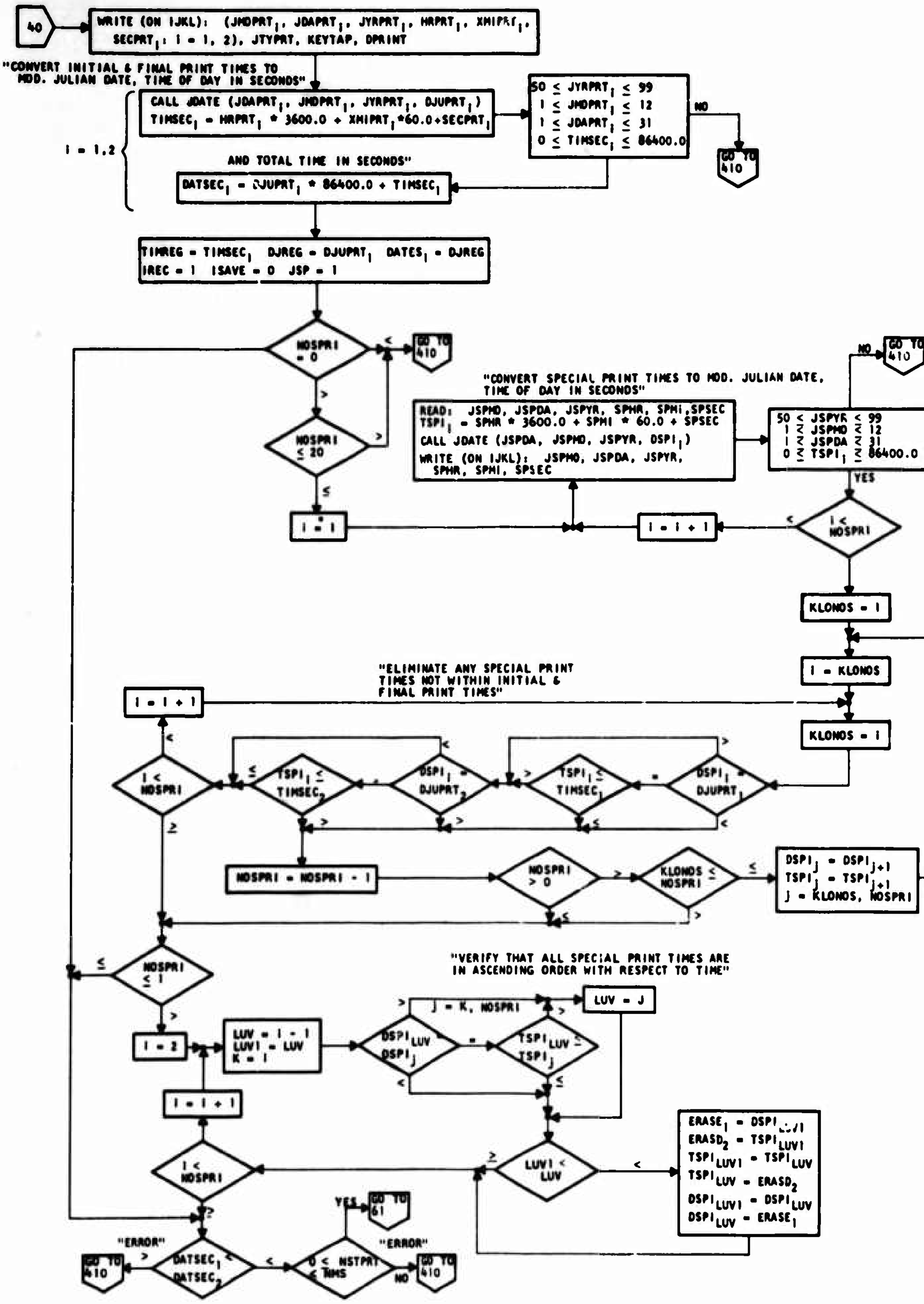
THIS IS THE MAIN PROGRAM OF THE FIRST DEPENDENT LINK.AFILT2 READS THE DATA (EXCEPT FOR THE OBSERVATION CARDS),PRINTS OUT THE INPUT DATA, CHECKS FOR ANY INPUT DATA ERROR AND COMPUTES CERTAIN INITIALIZATION. IF THERE ARE ANY DATA ERRORS,THE PROGRAM WILL PRINT OUT AN APPROPRIATE ERROR MESSAGE AND WILL CONTINUE WITH THE NEXT PROBLEM.

VARIABLE	EQUA	REF	DEFINITION
ERASD(1-2)			INTERMEDIATE VARIABLES
ERASE(1-4)			INTERMEDIATE VARIABLES
MERASE(1)			=0,FIRST TIME THROUGH THE PROGRAM LOOP =1,NOT THE FIRST TIME THROUGH THE PROGRAM LOOP OR SEE INPUT LISTING OR =-1,INPUT ERROR,PROGRAM WILL NOT CONTINUE =1,NO DISABLING INPUT ERROR,PROGRAM WILL CONTINUE
MERASE(2-3)			STORAGE CELLS



START
MERASE1 = 0
READ: TITLE (1-11), NOSAT, NOB, NAT, MERASE1, KOBSPR, KCOUNT, ISMOOH, NSTPRT, PASS, TNEXOS, IREVO, TIMTOL
JACK = 0
IONE = 0
CALL SETCON (JACK)
"ERROR"
0<NMS≤60
NO
GO TO 410
YES
JACK = 1
CTIN (6) = 95
PMATi,j = 0.0
i = 1,..., 6; j = 1,..., 6
READ: NUMSTAi, NSGi, SLONi, PHILATi, ALTi; i = 1,...., NMS
READ: OMSAT, SSAT, CDRAG, MOBS (2-4), ZDAT (1-3), AXSEMI, ECCEN, OINCL, WASC, WPERI, XMEAN, (PMATi,i; i = 1,...., 6) QP (1-2), Q (1-7), CT (1-9)
LINES = 60
IPAGE = 1
WRITE: TITLE (1-11)
NOB = 0
READ: ELEMIN, ELEMAX
MERASE1 = 0
READ: ZONHAR (1-5) REARTH, F, OMU
READ: DPRINT, (JHOPRTi, JDAPRTi, JYRPRTi, HRPRTi, XMIPRTi, SECPRTi, i = 1, 2) NOSPRI, JTYPRT, KEYTAP
"ERROR"
GO TO 410
JTYPRT = 0
JTYPRT ≤ 5
KEYTAP ≤ 0
IONE = 0
JTYPRT ≤ 2
NSTPRT ≤ 0
"ERROR"
GO TO 410
LUP = 1
REWIND MBCD
IONE = 1
MERASE3 = MBCD
LUP = 2
MERASE2 = IOUT
WRITE (ON IJKL): IREVO, MOBS (2-4), ZDAT (1-3), AXSEMI, ECCEN, OINCL, WASC, WPERI, XMEAN, (PMATi,i; i = 1,...6), QP (1-2) Q (1-7)
IJKL = MERASEj+1
j = 1, LUP
CALL SETCON (JACK)
WRITE (ON IJKL): CT (1-9), OMSAT, SSAT, CDRAG, REARTH, F, OMU, ZONHAR (1-5), NOB, NAT, MERASE1, KOBSPR, KCOUNT, ISMOOH, NSTPRT, PASS, TIMTOL
ERASE1 = SLONi/FLRAD
ERASE2 = SLATi/FLRAD
ERASE3 = PHILATi/FLRAD
ERASE4 = ALTi * REARTH
i = 1,...., NMS
WRITE (ON IJKL): NUMSTAi, NSGi, ERASE (1-4), SRADi
JTYPRT
≠ 0
DPRINT ≤ 0.0
≤ 0
"ERROR"
GO TO 410
GO TO 61
GO TO 40

FIG. 5.



40
WRITE (ON IJKL): (JMOPRT$_I$, JDAPRT$_I$, JYRPRT$_I$, HRPRT$_I$, XMIPRT$_I$, SECPRT$_I$: I = 1, 2), JTYPRT, KEYTAP, DPRINT
"CONVERT INITIAL & FINAL PRINT TIMES TO MOD. JULIAN DATE, TIME OF DAY IN SECONDS"
CALL JDATE (JDAPRT$_I$, JMOPRT$_I$, JYRPRT$_I$, DJUPRT$_I$)
TIMSEC$_I$ = HRPRT$_I$ * 3600.0 + XMIPRT$_I$*60.0+SECPRT$_I$
I = 1,2
50 ≤ JYRPRT$_I$ ≤ 99
1 ≤ JMOPRT$_I$ ≤ 12
1 ≤ JDAPRT$_I$ ≤ 31
0 ≤ TIMSEC$_I$ ≤ 86400.0
NO
GO TO 410
AND TOTAL TIME IN SECONDS"
DATSEC$_I$ = DJUPRT$_I$ * 86400.0 + TIMSEC$_I$
TIMREG = TIMSEC$_I$ DJREG = DJUPRT$_I$ DATES$_I$ = DJREG
IREC = 1 ISAVE = 0 JSP = 1
NOSPRI = 0
GO TO 410
NOSPRI ≤ 20
I = 1
"CONVERT SPECIAL PRINT TIMES TO MOD. JULIAN DATE, TIME OF DAY IN SECONDS"
READ: JSPMO, JSPDA, JSPYR, SPHR, SPMI, SPSEC
TSPI$_I$ = SPHR * 3600.0 + SPMI * 60.0 + SPSEC
CALL JDATE (JSPDA, JSPMO, JSPYR, DSPI$_I$)
WRITE (ON IJKL): JSPMO, JSPDA, JSPYR, SPHR, SPMI, SPSEC
50 ≤ JSPYR ≤ 99
1 ≤ JSPMO ≤ 12
1 ≤ JSPDA ≤ 31
0 ≤ TSPI$_I$ ≤ 86400.0
YES
NO
GO TO 410
I = I + 1
I < NOSPRI
KLONOS = 1
I = KLONOS
"ELIMINATE ANY SPECIAL PRINT TIMES NOT WITHIN INITIAL & FINAL PRINT TIMES"
I = I + 1
KLONOS = I
I < NOSPRI
TSPI$_I$ ≤ TIMSEC$_2$
DSPI$_I$ = DJUPRT$_2$
TSPI$_I$ ≤ TIMSEC$_1$
DSPI$_I$ = DJUPRT$_1$
NOSPRI = NOSPRI - 1
NOSPRI > 0
KLONOS ≤ NOSPRI
DSPI$_J$ = DSPI$_{J+1}$
TSPI$_J$ = TSPI$_{J+1}$
J = KLONOS, NOSPRI
NOSPRI ≤ 1
"VERIFY THAT ALL SPECIAL PRINT TIMES ARE IN ASCENDING ORDER WITH RESPECT TO TIME"
I = 2
LUV = I - 1
LUVI = LUV
K = I
J = K, NOSPRI
LUV = J
DSPI$_{LUV}$ DSPI$_J$
TSPI$_{LUV}$ ≤ TSPI$_J$
I = I + 1
I < NOSPRI
LUVI < LUV
ERASE$_1$ = DSPI$_{LUVI}$
ERASD$_2$ = TSPI$_{LUVI}$
TSPI$_{LUVI}$ = TSPI$_{LUV}$
TSPI$_{LUV}$ = ERASD$_2$
DSPI$_{LUVI}$ = DSPI$_{LUV}$
DSPI$_{LUV}$ = ERASE$_1$
"ERROR"
GO TO 410
DATSEC$_1$ < DATSEC$_2$
YES
GO TO 61
0 < NSTPRT TIMS
"ERROR"
NO
GO TO 410

FIG. 6.

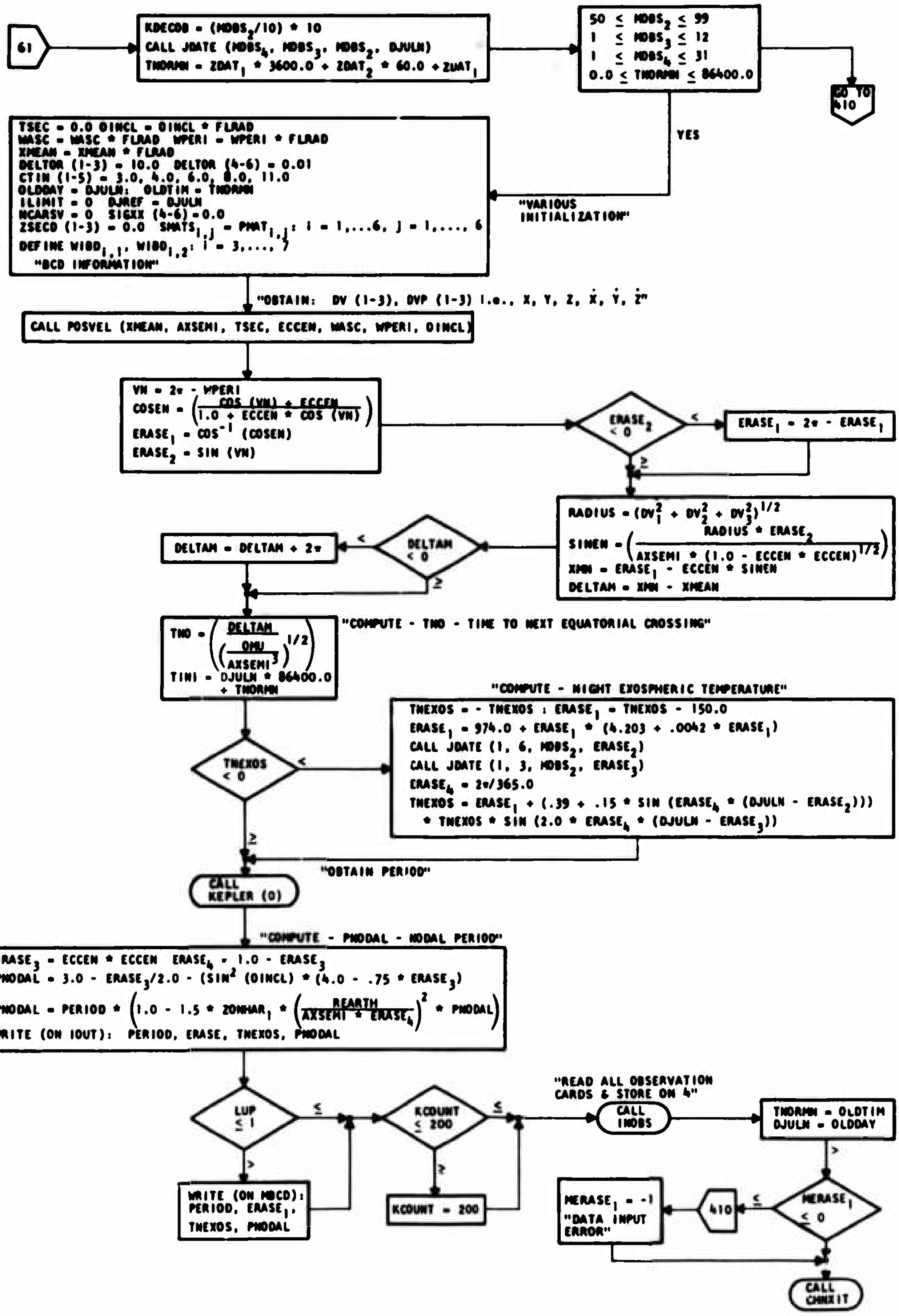

61
KDECOD = (MOBS2/10) * 10
CALL JDATE (MOBS4, MOBS3, MOBS2, DJULN)
THORMN = ZDAT1 * 3600.0 + ZDAT2 * 60.0 + ZDAT1
50 ≤ MOBS2 ≤ 99
1 ≤ MOBS3 ≤ 12
1 ≤ MOBS4 ≤ 31
0.0 ≤ THORMN ≤ 86400.0
GO TO 410
YES
TSEC = 0.0 OINCL = OINCL * FLRAD
WASC = WASC * FLRAD WPERI = WPERI * FLRAD
XMEAN = XMEAN * FLRAD
DELTOR (1-3) = 10.0 DELTOR (4-6) = 0.01
CTIN (1-5) = 3.0, 4.0, 6.0, 8.0, 11.0
OLDDAY = DJULN: OLDTIM = THORMN
ILIMIT = 0 DJREF = DJULN
NCARSV = 0 SIGXX (4-6) = 0.0
ZSECD (1-3) = 0.0 SMATS i,j = PMAT i,j: i = 1,...6, j = 1,...., 6
DEFINE WIBD i,1, WIBD i,2: i = 3,...., 7
"BCD INFORMATION"
"VARIOUS INITIALIZATION"
"OBTAIN: DV (1-3), DVP (1-3) i.e., X, Y, Z, Ẋ, Ẏ, Ż"
CALL POSVEL (XMEAN, AXSEMI, TSEC, ECCEN, WASC, WPERI, OINCL)
VN = 2π - WPERI
COSEN = (COS (VN) + ECCEN / 1.0 + ECCEN * COS (VN))
ERASE1 = COS⁻¹ (COSEN)
ERASE2 = SIN (VN)
ERASE2 < 0
ERASE1 = 2π - ERASE1
RADIUS = (DV1² + DV2² + DV3²)^1/2
SINEN = (RADIUS * ERASE2 / AXSEMI * (1.0 - ECCEN * ECCEN)^1/2)
XMN = ERASE1 - ECCEN * SINEN
DELTAM = XMN - XMEAN
DELTAM < 0
DELTAM = DELTAM + 2π
TNO = (DELTAM / (OMU / AXSEMI³)^1/2)
TINI = DJULN * 86400.0 + THORMN
"COMPUTE - TNO - TIME TO NEXT EQUATORIAL CROSSING"
"COMPUTE - NIGHT EXOSPHERIC TEMPERATURE"
THEXOS = - THEXOS : ERASE1 = THEXOS - 150.0
ERASE1 = 974.0 + ERASE1 * (4.203 + .0042 * ERASE1)
CALL JDATE (1, 6, MOBS2, ERASE2)
CALL JDATE (1, 3, MOBS2, ERASE3)
ERASE4 = 2π/365.0
THEXOS = ERASE1 + (.39 + .15 * SIN (ERASE4 * (DJULN - ERASE2)))
* THEXOS * SIN (2.0 * ERASE4 * (DJULN - ERASE3))
THEXOS < 0
"OBTAIN PERIOD"
CALL KEPLER (0)
"COMPUTE - PNODAL - NODAL PERIOD"
ERASE3 = ECCEN * ECCEN ERASE4 = 1.0 - ERASE3
PNODAL = 3.0 - ERASE3/2.0 - (SIN² (OINCL) * (4.0 - .75 * ERASE3)
PNODAL = PERIOD * (1.0 - 1.5 * ZONHAR1 * (REARTH / AXSEMI * ERASE4)² * PNODAL)
WRITE (ON IOUT): PERIOD, ERASE, THEXOS, PNODAL
LUP ≤ 1
KCOUNT ≤ 200
"READ ALL OBSERVATION CARDS & STORE ON 4"
CALL INOBS
THORMN = OLDTIM
DJULN = OLDDAY
WRITE (ON MBCD): PERIOD, ERASE1, THEXOS, PNODAL
KCOUNT = 200
MERASE1 = -1
"DATA INPUT ERROR"
410
MERASE1 ≤ 0
CALL CHNXIT

FIG. 7.

DFILT2

THIS IS THE MAIN PROGRAM OF THE SECOND DEPENDENT LINK.THE MAIN FUNCTION IS TO COMPUTE THE FILTERING EQUATIONS,TO PRINT THE OUTPUT, TO REJECT ANY OBSERVATION CARDS AND TO ITERATE.

VARIABLE	EQUA	REF	DEFINITION
DIAG(6,6)	52 2	1	INTERMEDIATE MATRIX OR THE INVERSE OF THE PHI MATRIX
ERASD(1)			INTERMEDIATE VARIABLE
ERASE(1-20)			INTERMEDIATE VARIABLES OR
ERASE(1-9)	A.15		IMPROVED STANDARD OBSERVATION ERRORS COMPUTED AT THE END OF EACH FILTERING PHASE,OUTPUT
ERASE(1-6)	19	1	CORRECTION TO POSITION AND VELOCITY VECTOR, OUTPUT
ERASE(7-12)	52	1	STANDARD DEVIATIONS(SQUARE ROOT OF THE DIAGONAL ELEMENTS OF PMAT) OF THE POSITION AND VELOCITY ERROR,OUTPUT
ERASE(7)	A.16		INTERMEDIATE VARIABLE
ERASE(19)	A.16A		INTERMEDIATE VARIABLE
ERASE(20)	A.16A		INTERMEDIATE VARIABLE
HPHTR(7,7) HPHTR(6,6)	53 2	1	R MATRIX, OR ITS INVERSE OR PHI MATRIX OR ITS INVERSE
ICOUNT			ITERATION COUNTER
MERASE(1)			=-20,ALTITUDE BELOW 120.0(KM), OR EXOSPHERIC TEMPERATURE OUTSIDE OF 500°K - 2400°K RANGE.PROGRAM WILL NOT CONTINUE =1,COMPUTE HIGHER ORDER TERMS OF THE EARTH'S GRAVITATIONAL POTENTIAL FUNCTION AND THE DRAG TERM IN THE DIFFERENTIAL EQUATION SUBROUTINE
P12(3,3)	15	1	NUTATION-PRECESSION MATRIX (COMPUTED AT DJULN)

P2(3,3)	13	1	PRECESSION MATRIX (COMPUTED AT DJULN)
PHITR(6,6)	52	1	INTERMEDIATE MATRIX

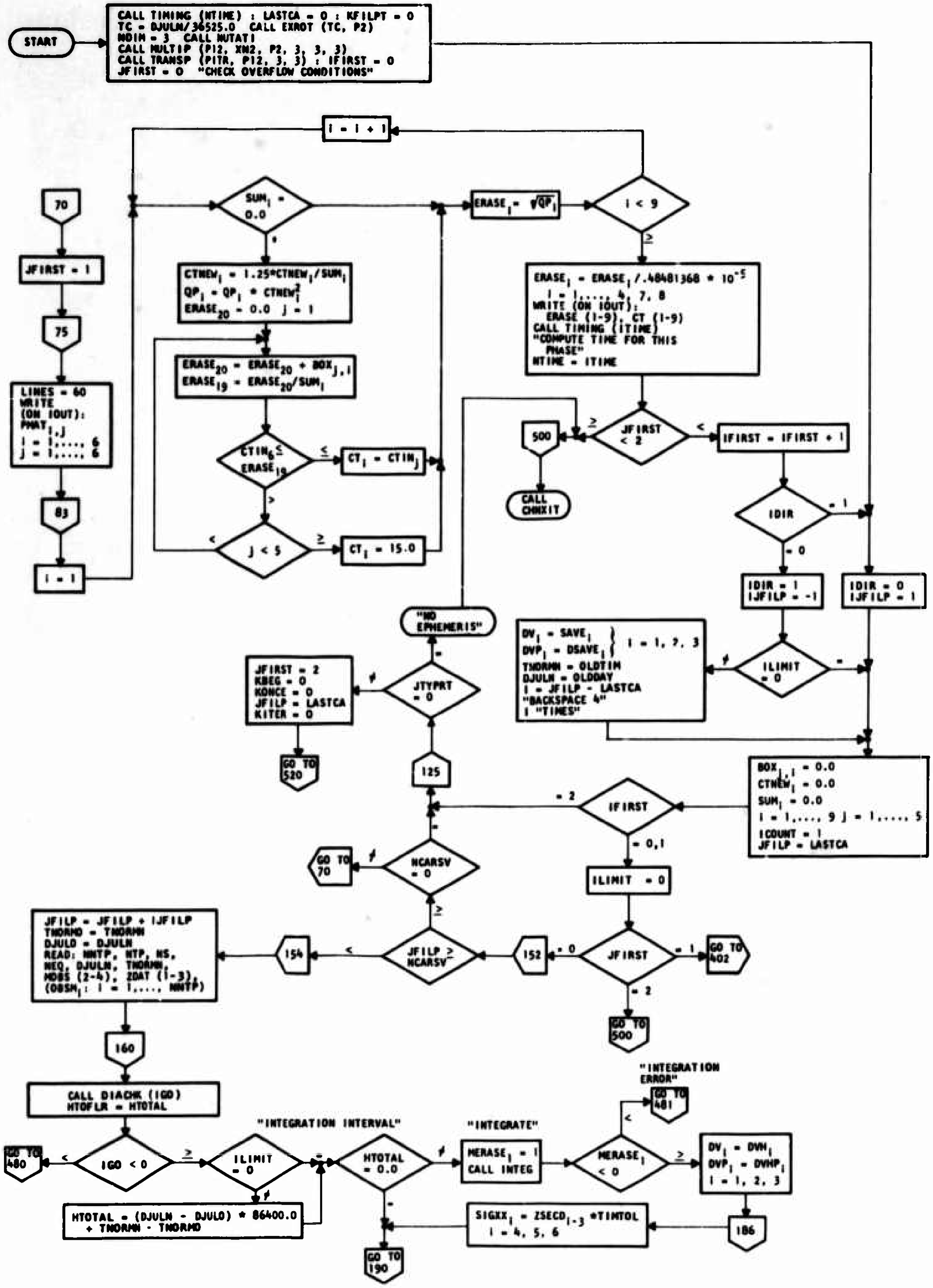

START
CALL TIMING (NTIME) : LASTCA = 0 : KFILPT = 0
TC = DJULN/36525.0 CALL EXROT (TC, P2)
NDIM = 3 CALL NUTATI
CALL MULTIP (P12, XN2, P2, 3, 3, 3)
CALL TRANSP (PITR, P12, 3, 3) : IFIRST = 0
JFIRST = 0 "CHECK OVERFLOW CONDITIONS"
I = I + 1
70
JFIRST = 1
75
LINES = 60
WRITE
(ON IOUT):
PMAT I,J
I = 1,...., 6
J = 1,...., 6
83
I = 1
SUM I = 0.0
CTNEW I = 1.25*CTNEW I/SUM I
QP I = QP I * CTNEW I 2
ERASE 20 = 0.0 J = 1
ERASE 20 = ERASE 20 + BOX J,I
ERASE 19 = ERASE 20/SUM I
CTIN 6 ≤ ERASE 19
CT I = CTIN J
J < 5
CT I = 15.0
ERASE I = √QP I
I < 9
ERASE I = ERASE I /.48481368 * 10^-5
I = 1,...., 4, 7, 8
WRITE (ON IOUT):
ERASE (1-9), CT (1-9)
CALL TIMING (ITIME)
"COMPUTE TIME FOR THIS PHASE"
NTIME = ITIME
500
CALL CHNXIT
JFIRST < 2
IFIRST = IFIRST + 1
IDIR
IDIR = 1
IJFILP = -1
IDIR = 0
IJFILP = 1
"NO EPHEMERIS"
DV I = SAVE I
DVP I = DSAVE I
I = 1, 2, 3
THORMN = OLDTIM
DJULN = OLDDAY
I = JFILP - LASTCA
"BACKSPACE 4"
I "TIMES"
ILIMIT = 0
JFIRST = 2
KBEG = 0
KONCE = 0
JFILP = LASTCA
KITER = 0
JTYPRT = 0
GO TO 520
125
BOX J,I = 0.0
CTNEW I = 0.0
SUM I = 0.0
I = 1,...., 9 J = 1,...., 5
ICOUNT = 1
JFILP = LASTCA
IFIRST
GO TO 70
NCARSV = 0
ILIMIT = 0
JFILP = JFILP + IJFILP
THORMO = THORMN
DJULO = DJULN
READ: NNTP, NTP, NS,
NEQ, DJULN, THORMN,
NOBS (2-4), ZDAT (1-3),
(OBSM I : I = 1,...., NNTP)
154
JFILP ≥ NCARSV
152
JFIRST
GO TO 402
GO TO 500
160
CALL DIACHK (IGO)
HTOFLR = HTOTAL
"INTEGRATION ERROR"
GO TO 481
"INTEGRATION INTERVAL"
"INTEGRATE"
GO TO 480
IGO < 0
ILIMIT = 0
HTOTAL = 0.0
NERASE I = 1
CALL INTEG
NERASE I < 0
DV I = DVN I
DVP I = DVNP I
I = 1, 2, 3
HTOTAL = (DJULN - DJULO) * 86400.0
+ THORMN - THORMO
SIGXX I = ZSECD I-3 *TIMTOL
I = 4, 5, 6
186
GO TO 190

FIG. 8.

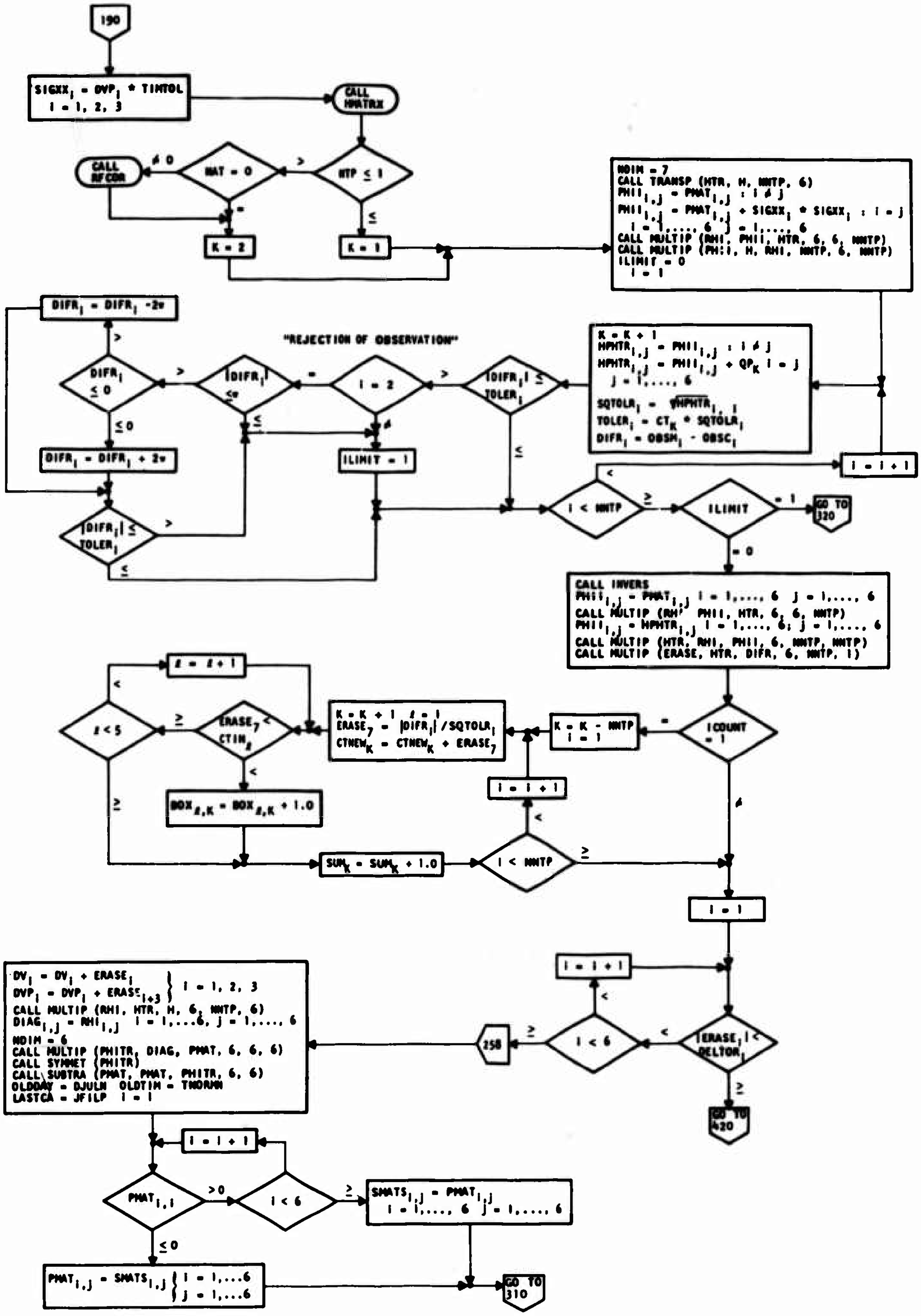


FIG. 9.

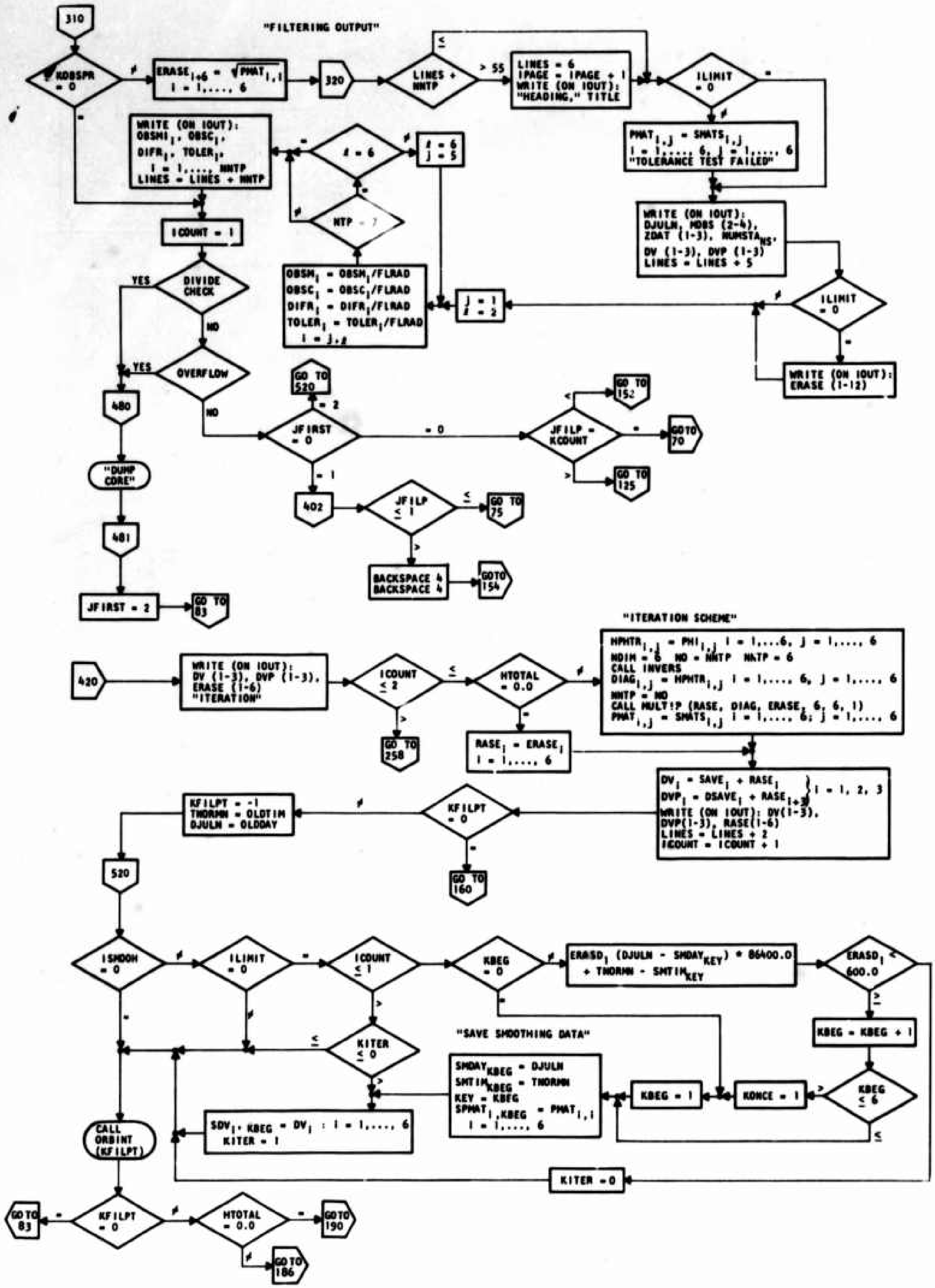

"FILTERING OUTPUT"
"ITERATION SCHEME"
"SAVE SMOOTHING DATA"
"DUMP CORE"
CALL ORBINT (KFILPT)
BACKSPACE 4
BACKSPACE 4
JFIRST = 2
KITER = 0

FIG. 10.

B. SUBROUTINES

SUBROUTINE CDATE AND SUBROUTINE JDATE

CDATE CALCULATES THE CALENDAR DATE (DAY,MONTH,YEAR) GIVEN THE MODIFIED JULIAN DATE.

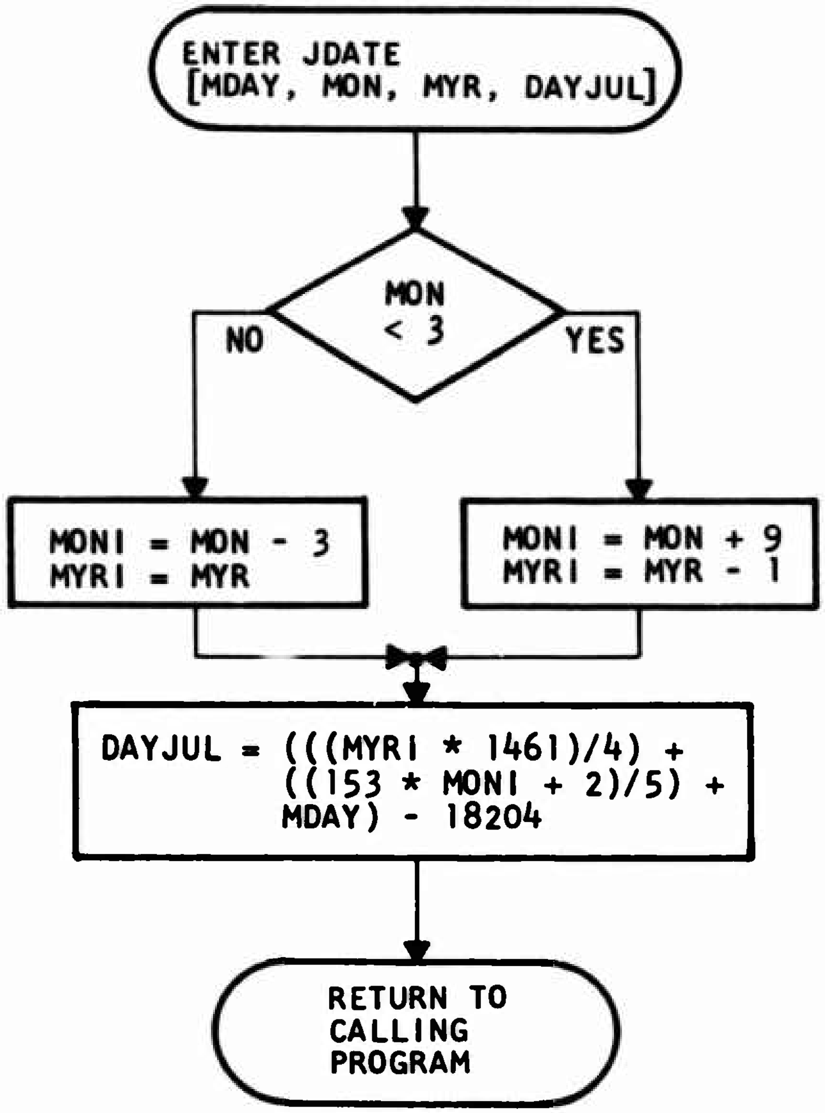
JDATE CALCULATES THE MODIFIED JULIAN DATE GIVEN THE CALENDAR DATE(DAY,MONTH,YEAR)

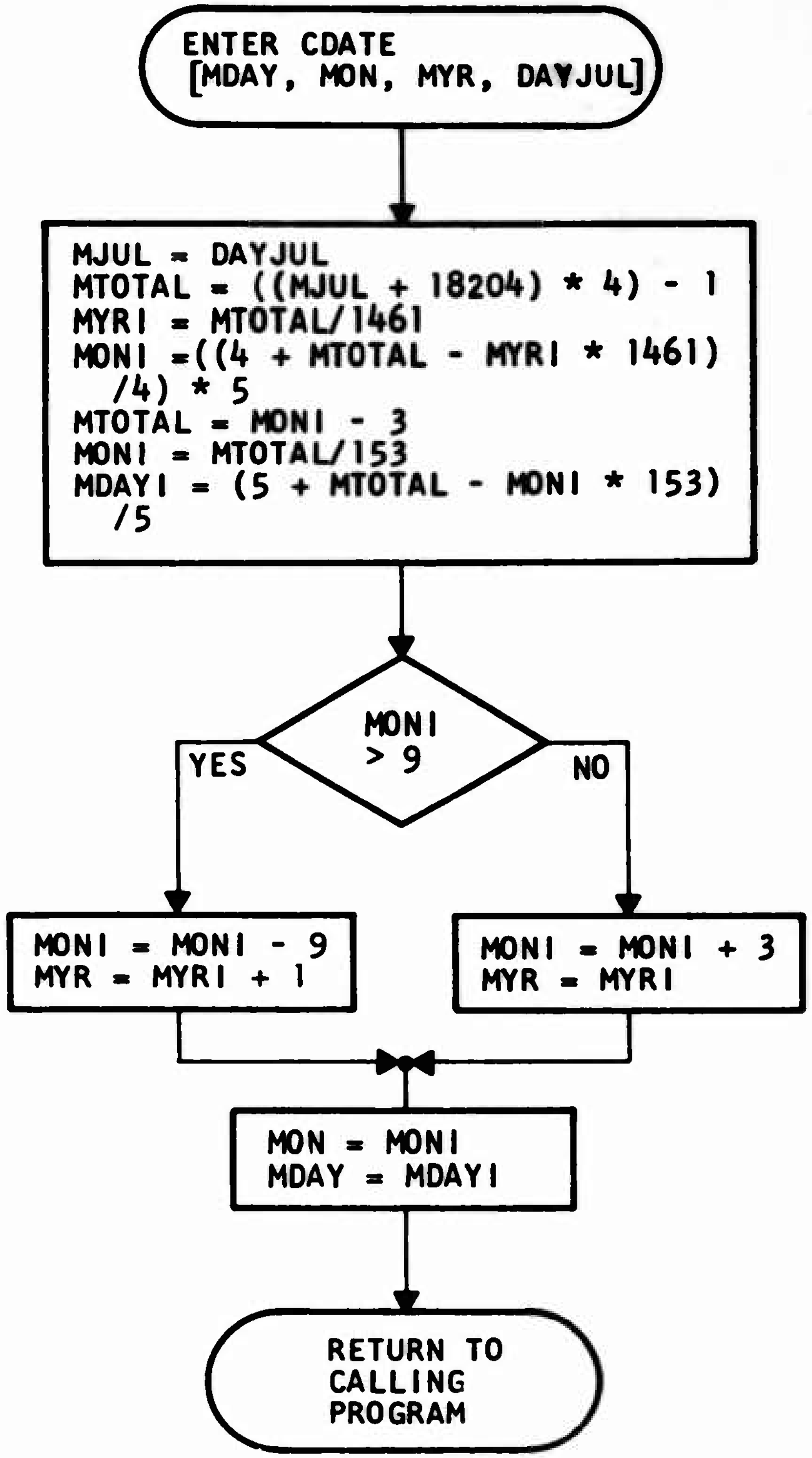
NOTE 1) THE MODIFIED JULIAN DATE IS THE NUMBER OF INTEGRAL DAYS SINCE JANUARY 1,1950 (0^hUT)

2) THE YEAR IS DEFINED TO BE THE LAST 2 DIGITS OF 19XX.

3) THE VALID CALENDAR DATES FOR THIS SUBROUTINE ARE
JANUARY 1,1950 (0^hUT) TO
DECEMBER 1,1999 (0^hUT)

4) THE VARIABLES USED IN THE 2 SUBROUTINES HAVE NOT BEEN DEFINED IN THE LIST OF SYMBOLS.


ENTER JDATE
[MDAY, MON, MYR, DAYJUL]
MON
< 3
NO
YES
MONI = MON - 3
MYRI = MYR
MONI = MON + 9
MYRI = MYR - 1
DAYJUL = (((MYRI * 1461)/4) +
((153 * MONI + 2)/5) +
MDAY) - 18204
RETURN TO
CALLING
PROGRAM


ENTER CDATE
[MDAY, MON, MYR, DAYJUL]
MJUL = DAYJUL
MTOTAL = ((MJUL + 18204) * 4) - 1
MYRI = MTOTAL/1461
MONI =((4 + MTOTAL - MYRI * 1461)
/4) * 5
MTOTAL = MONI - 3
MONI = MTOTAL/153
MDAYI = (5 + MTOTAL - MONI * 153)
/5
MONI
> 9
YES
NO
MONI = MONI - 9
MYR = MYRI + 1
MONI = MONI + 3
MYR = MYRI
MON = MONI
MDAY = MDAYI
RETURN TO
CALLING
PROGRAM

SUBROUTINE DENSIT

THIS SUBROUTINE COMPUTES THE DENSITY AS A FUNCTION OF ALTITUDE AND EXOSPHERIC TEMPERATURE.

VARIABLE	EQUA	REF	DEFINITION
ERASE(2)			DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH(KM)
ERASE(20)	5	2	EXOSPHERIC TEMPERATURE (DEG K)
TEMP	177B, 177C	1	INTERMEDIATE VARIABLE

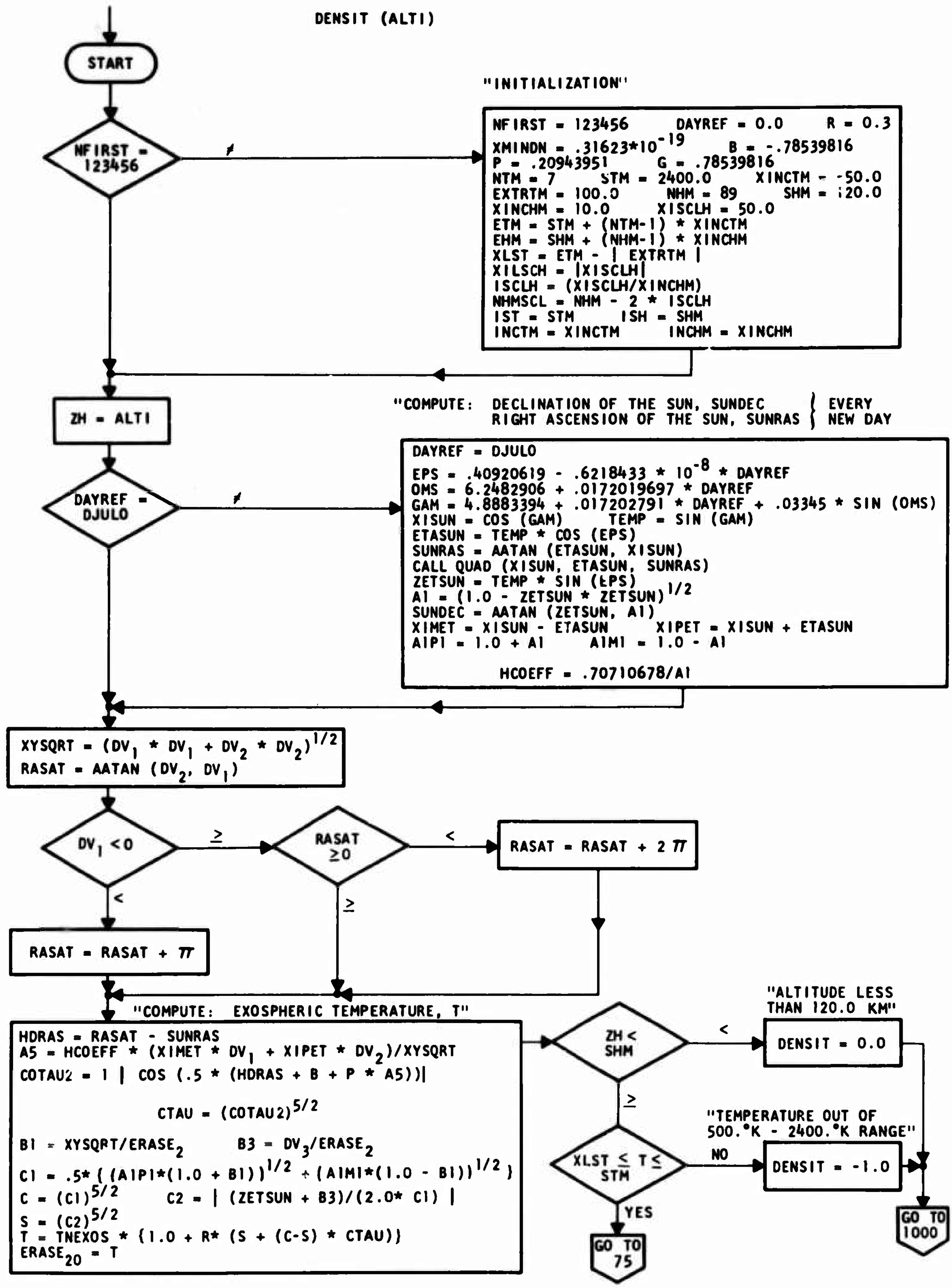

DENSIT (ALTI)
START
NFIRST = 123456
"INITIALIZATION"
NFIRST = 123456 DAYREF = 0.0 R = 0.3
XMINDN = .31623*10^-19 B = -.78539816
P = .20943951 G = .78539816
NTM = 7 STM = 2400.0 XINCTM = -50.0
EXTRTM = 100.0 NHM = 89 SHM = 120.0
XINCHM = 10.0 XISCLH = 50.0
ETM = STM + (NTM-1) * XINCTM
EHM = SHM + (NHM-1) * XINCHM
XLST = ETM - | EXTRTM |
XILSCH = |XISCLH|
ISCLH = (XISCLH/XINCHM)
NHMSCL = NHM - 2 * ISCLH
IST = STM ISH = SHM
INCTM = XINCTM INCHM = XINCHM
ZH = ALTI
DAYREF = DJULO
"COMPUTE: DECLINATION OF THE SUN, SUNDEC RIGHT ASCENSION OF THE SUN, SUNRAS EVERY NEW DAY
DAYREF = DJULO
EPS = .40920619 - .6218433 * 10^-8 * DAYREF
OMS = 6.2482906 + .0172019697 * DAYREF
GAM = 4.8883394 + .017202791 * DAYREF + .03345 * SIN (OMS)
XISUN = COS (GAM) TEMP = SIN (GAM)
ETASUN = TEMP * COS (EPS)
SUNRAS = AATAN (ETASUN, XISUN)
CALL QUAD (XISUN, ETASUN, SUNRAS)
ZETSUN = TEMP * SIN (EPS)
A1 = (1.0 - ZETSUN * ZETSUN)^1/2
SUNDEC = AATAN (ZETSUN, A1)
XIMET = XISUN - ETASUN XIPET = XISUN + ETASUN
A1P1 = 1.0 + A1 A1M1 = 1.0 - A1
HCOEFF = .70710678/A1
XYSQRT = (DV1 * DV1 + DV2 * DV2)^1/2
RASAT = AATAN (DV2, DV1)
DV1 < 0
≥
<
RASAT ≥ 0
<
≥
RASAT = RASAT + 2 π
RASAT = RASAT + π
"COMPUTE: EXOSPHERIC TEMPERATURE, T"
HDRAS = RASAT - SUNRAS
A5 = HCOEFF * (XIMET * DV1 + XIPET * DV2)/XYSQRT
COTAU2 = 1 | COS (.5 * (HDRAS + B + P * A5))|
CTAU = (COTAU2)^5/2
B1 = XYSQRT/ERASE2 B3 = DV3/ERASE2
C1 = .5* {(A1P1*(1.0 + B1))^1/2 + (A1M1*(1.0 - B1))^1/2}
C = (C1)^5/2 C2 = | (ZETSUN + B3)/(2.0* C1) |
S = (C2)^5/2
T = TNEXOS * (1.0 + R* (S + (C-S) * CTAU))
ERASE20 = T
ZH < SHM
<
"ALTITUDE LESS THAN 120.0 KM"
DENSIT = 0.0
≥
"TEMPERATURE OUT OF 500.°K - 2400.°K RANGE"
XLST ≤ T ≤ STM
NO
DENSIT = -1.0
YES
GO TO 75
GO TO 1000

FIG. 12.

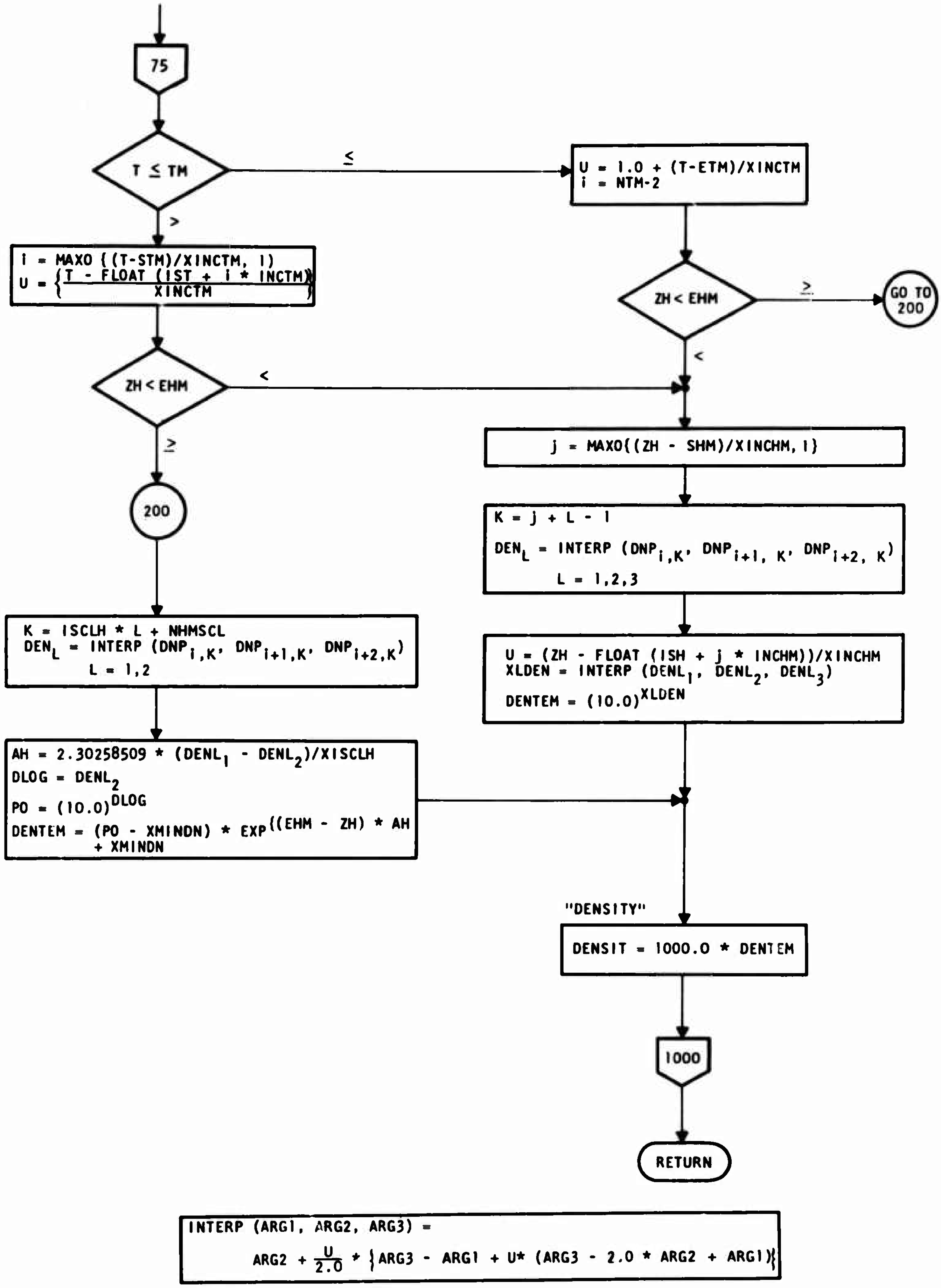

75
T ≤ TM
≤
U = 1.0 + (T-ETM)/XINCTM
i = NTM-2
>
i = MAXO {(T-STM)/XINCTM, 1)
U = {T - FLOAT (IST + i * INCTM)} / XINCTM
ZH < EHM
≥
GO TO 200
<
ZH < EHM
<
j = MAXO((ZH - SHM)/XINCHM, 1)
≥
200
K = j + L - 1
DEN_L = INTERP (DNP_i,K, DNP_i+1,K, DNP_i+2,K)
L = 1,2,3
K = ISCLH * L + NHMSCL
DEN_L = INTERP (DNP_i,K, DNP_i+1,K, DNP_i+2,K)
L = 1,2
U = (ZH - FLOAT (ISH + j * INCHM))/XINCHM
XLDEN = INTERP (DENL_1, DENL_2, DENL_3)
DENTEM = (10.0)^XLDEN
AH = 2.30258509 * (DENL_1 - DENL_2)/XISCLH
DLOG = DENL_2
PO = (10.0)^DLOG
DENTEM = (PO - XMINDN) * EXP((EHM - ZH) * AH
+ XMINDN
"DENSITY"
DENSIT = 1000.0 * DENTEM
1000
RETURN
INTERP (ARG1, ARG2, ARG3) =
ARG2 + U/2.0 * {ARG3 - ARG1 + U* (ARG3 - 2.0 * ARG2 + ARG1)}

FIG. 13.

SUBROUTINE DIACHK

THE MAIN FUNCTION OF THIS SUBROUTINE IS TO COMPUTE EQUATION 51, REFERENCE 1.

VARIABLE	EQUA	REF	DEFINITION
DIAG(6,6)	51	1	INTERMEDIATE MATRIX
ERASD(1)			INTERMEDIATE VARIABLE
ERASE(1)			INTERMEDIATE VARIABLE
MERASE(1)			STORAGE CELL
PHITR(6,6)	51	1	TRANSPOSE OF THE PHI(6,6) MATRIX

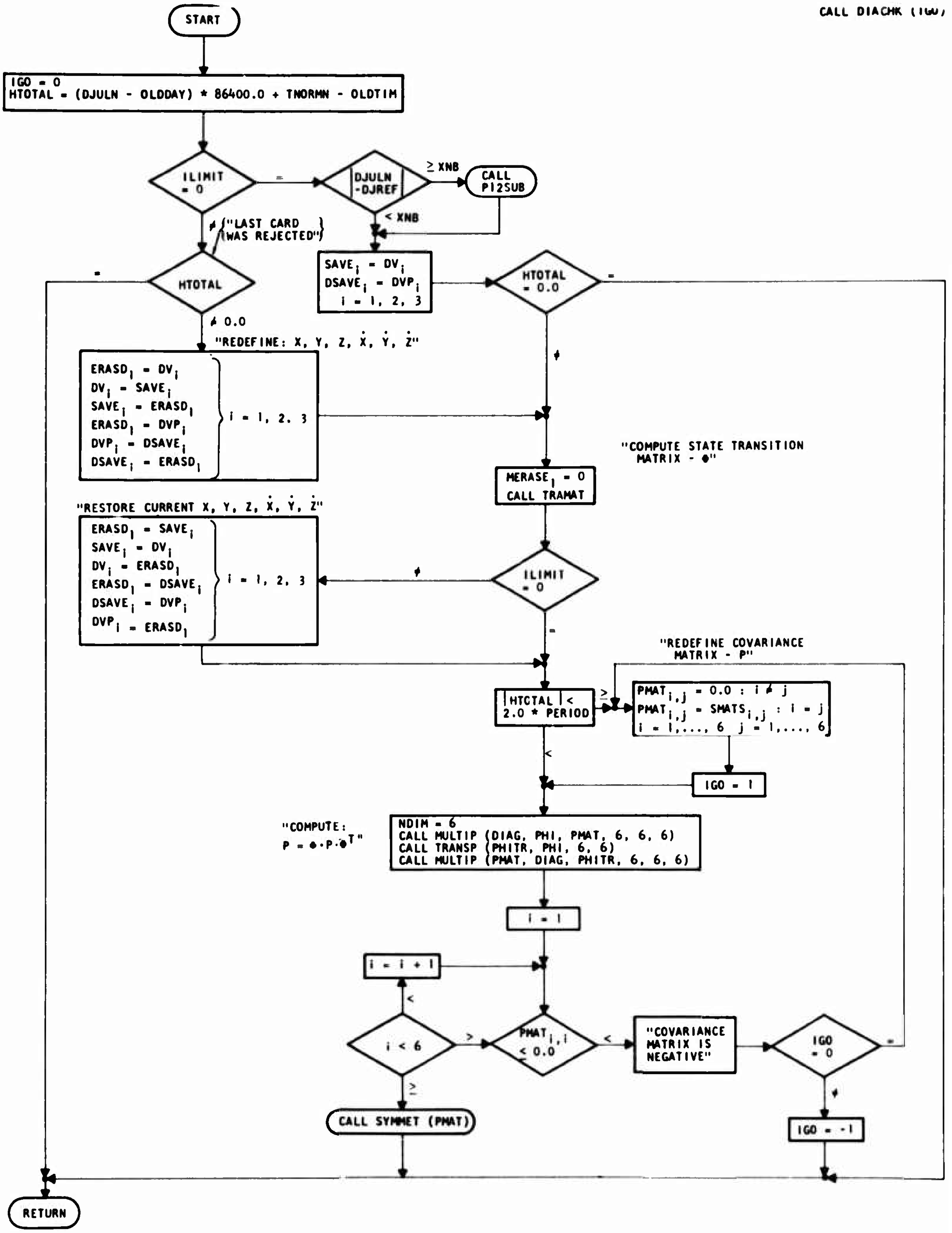

START
IGO = 0
HTOTAL = (DJULN - OLDDAY) * 86400.0 + TNORMN - OLDTIM
ILIMIT = 0
|DJULN -DJREF|
≥ XNB
CALL P12SUB
< XNB
"LAST CARD WAS REJECTED"
HTOTAL
≠ 0.0
SAVEi = DVi
DSAVEi = DVPi
i = 1, 2, 3
HTOTAL = 0.0
"REDEFINE: X, Y, Z, Ẋ, Ẏ, Ż"
ERASDi = DVi
DVi = SAVEi
SAVEi = ERASDi
ERASDi = DVPi
DVPi = DSAVEi
DSAVEi = ERASDi
i = 1, 2, 3
"COMPUTE STATE TRANSITION MATRIX - Φ"
MERASEi = 0
CALL TRAMAT
"RESTORE CURRENT X, Y, Z, Ẋ, Ẏ, Ż"
ERASDi = SAVEi
SAVEi = DVi
DVi = ERASDi
ERASDi = DSAVEi
DSAVEi = DVPi
DVPi = ERASDi
i = 1, 2, 3
ILIMIT = 0
"REDEFINE COVARIANCE MATRIX - P"
|HTOTAL| < 2.0 * PERIOD
PMATi,j = 0.0 : i ≠ j
PMATi,j = SMATSi,j : i = j
i = 1,..., 6 j = 1,..., 6
IGO = 1
"COMPUTE: P = Φ·P·ΦT"
NDIM = 6
CALL MULTIP (DIAG, PHI, PMAT, 6, 6, 6)
CALL TRANSP (PHITR, PHI, 6, 6)
CALL MULTIP (PMAT, DIAG, PHITR, 6, 6, 6)
i = 1
i = i + 1
i < 6
PMATi,i ≤ 0.0
"COVARIANCE MATRIX IS NEGATIVE"
IGO = 0
IGO = -1
CALL SYMMET (PMAT)
RETURN

FIG. 14.

SUBROUTINE EXROT

THIS SUBROUTINE COMPUTES THE PRECESSION MATRIX (EQUATION 13, REFERENCE 1.)

CALL EXROT (T, X)

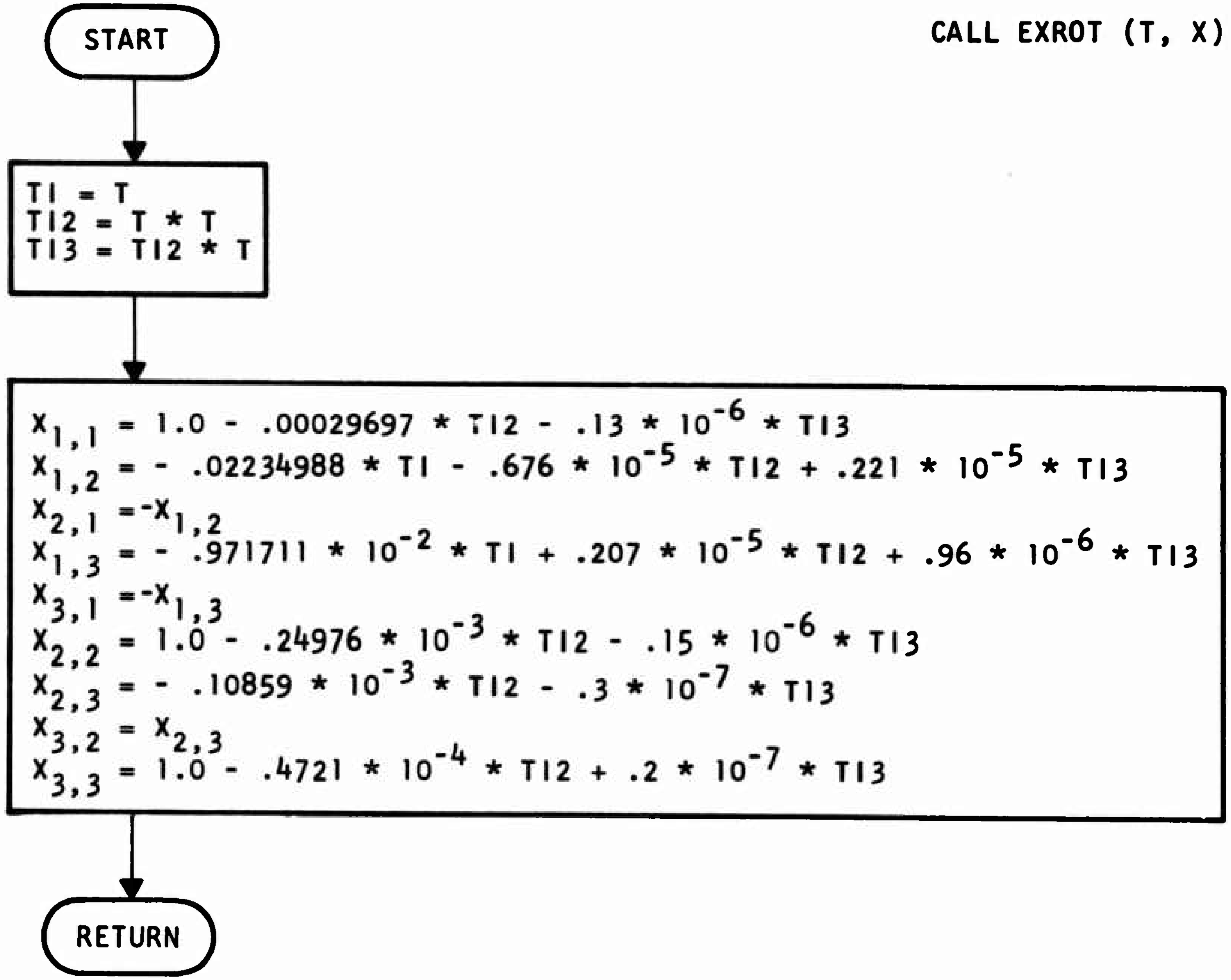


FIG. 15.

SUBROUTINE HMATRX

THIS SUBROUTINE COMPUTES THE DECLINATION ,RIGHT ASCENSION AND THE H MATRIX (SECTION VII B,REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
CON(1-3)	16,126, 127	1	INTERMEDIATE VARIABLES
CON(8)	17,147	1	INTERMEDIATE VARIABLE,$\dot{Z}$ OR $\ddot{Z}$
ERASE(1-8)	122-148	1	INTERMEDIATE VARIABLES
MERASE(1)			=1,STATION CAN SEE THE SATELLITE =-1,STATION CAN NOT SEE THE SATELLITE

CALL HMATRX

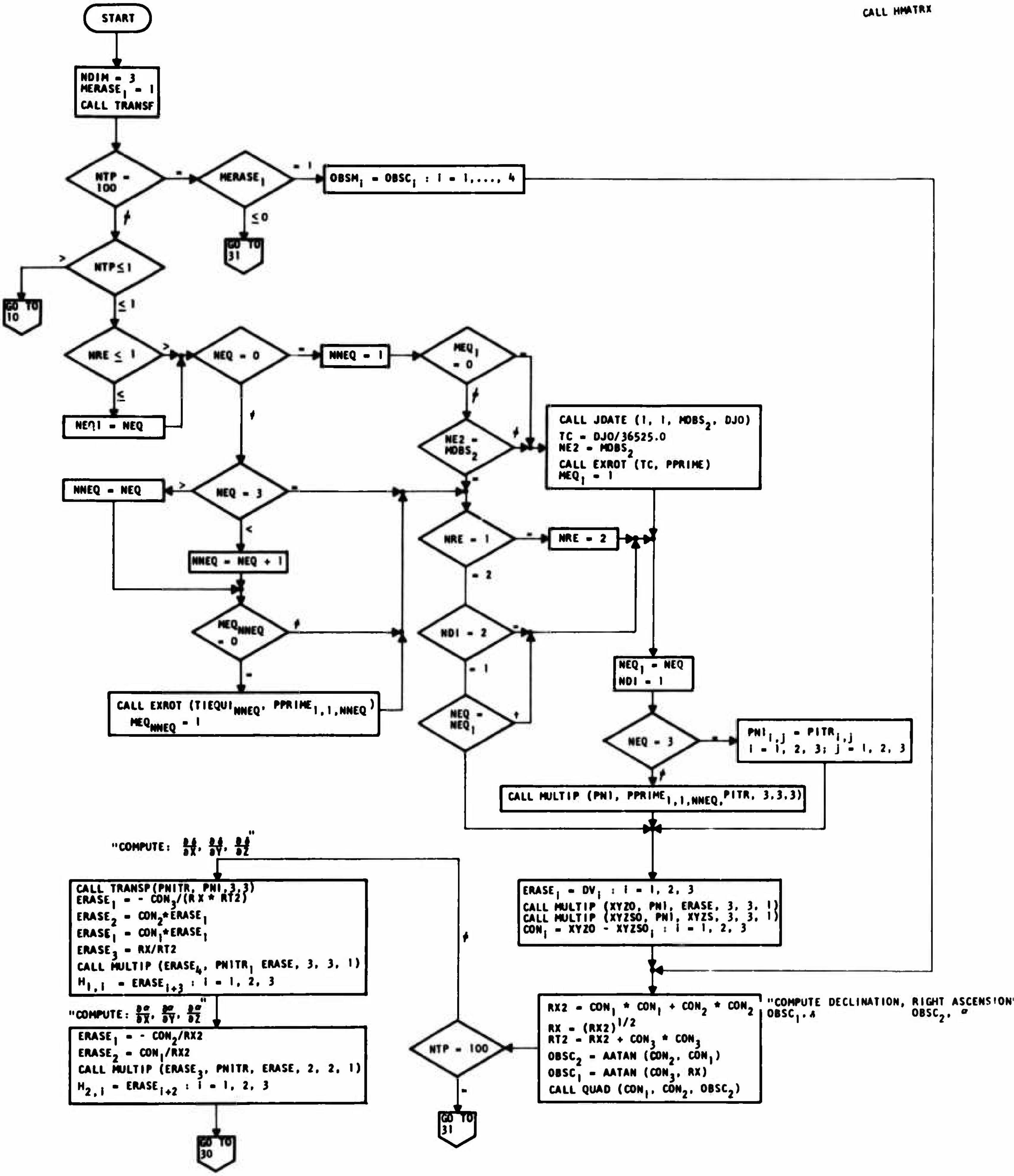


FIG. 16.

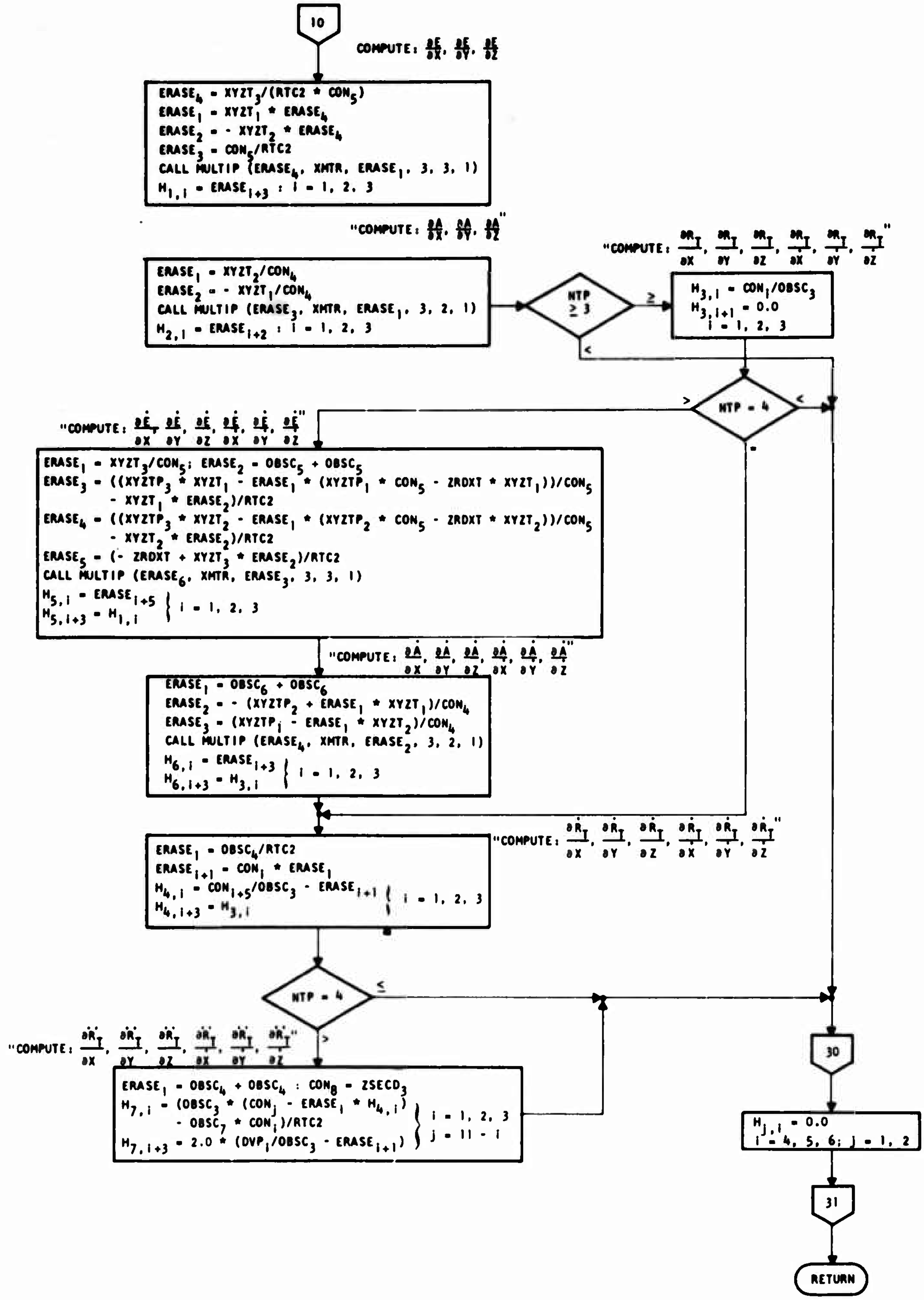

10
COMPUTE: ∂E/∂X, ∂E/∂Y, ∂E/∂Z
ERASE4 = XYZT3/(RTC2 * CON5)
ERASE1 = XYZT1 * ERASE4
ERASE2 = - XYZT2 * ERASE4
ERASE3 = CON5/RTC2
CALL MULTIP (ERASE4, XMTR, ERASE1, 3, 3, 1)
H1,I = ERASEI+3 : I = 1, 2, 3
"COMPUTE: ∂A/∂X, ∂A/∂Y, ∂A/∂Z"
ERASE1 = XYZT2/CON4
ERASE2 = - XYZT1/CON4
CALL MULTIP (ERASE3, XMTR, ERASE1, 3, 2, 1)
H2,I = ERASEI+2 : I = 1, 2, 3
NTP ≥ 3
"COMPUTE: ∂RI/∂X, ∂RI/∂Y, ∂RI/∂Z, ∂RI/∂Ẋ, ∂RI/∂Ẏ, ∂RI/∂Ż"
H3,I = CONI/OBSC3
H3,I+1 = 0.0
I = 1, 2, 3
NTP = 4
"COMPUTE: ∂Ė/∂X, ∂Ė/∂Y, ∂Ė/∂Z, ∂Ė/∂Ẋ, ∂Ė/∂Ẏ, ∂Ė/∂Ż"
ERASE1 = XYZT3/CON5; ERASE2 = OBSC5 + OBSC5
ERASE3 = ((XYZTP3 * XYZT1 - ERASE1 * (XYZTP1 * CON5 - ZRDXT * XYZT1))/CON5 - XYZT1 * ERASE2)/RTC2
ERASE4 = ((XYZTP3 * XYZT2 - ERASE1 * (XYZTP2 * CON5 - ZRDXT * XYZT2))/CON5 - XYZT2 * ERASE2)/RTC2
ERASE5 = (- ZRDXT + XYZT3 * ERASE2)/RTC2
CALL MULTIP (ERASE6, XMTR, ERASE3, 3, 3, 1)
H5,I = ERASEI+5
H5,I+3 = H1,I
I = 1, 2, 3
"COMPUTE: ∂Ȧ/∂X, ∂Ȧ/∂Y, ∂Ȧ/∂Z, ∂Ȧ/∂Ẋ, ∂Ȧ/∂Ẏ, ∂Ȧ/∂Ż"
ERASE1 = OBSC6 + OBSC6
ERASE2 = - (XYZTP2 + ERASE1 * XYZT1)/CON4
ERASE3 = (XYZTP1 - ERASE1 * XYZT2)/CON4
CALL MULTIP (ERASE4, XMTR, ERASE2, 3, 2, 1)
H6,I = ERASEI+3
H6,I+3 = H3,I
I = 1, 2, 3
"COMPUTE: ∂ṘI/∂X, ∂ṘI/∂Y, ∂ṘI/∂Z, ∂ṘI/∂Ẋ, ∂ṘI/∂Ẏ, ∂ṘI/∂Ż"
ERASE1 = OBSC4/RTC2
ERASEI+1 = CONI * ERASE1
H4,I = CONI+5/OBSC3 - ERASEI+1
H4,I+3 = H3,I
I = 1, 2, 3
NTP = 4
"COMPUTE: ∂R̈I/∂X, ∂R̈I/∂Y, ∂R̈I/∂Z, ∂R̈I/∂Ẋ, ∂R̈I/∂Ẏ, ∂R̈I/∂Ż"
ERASE1 = OBSC4 + OBSC4 : CON8 = ZSECD3
H7,I = (OBSC3 * (CONJ - ERASE1 * H4,I) - OBSC7 * CONI)/RTC2
H7,I+3 = 2.0 * (DVPI/OBSC3 - ERASEI+1)
I = 1, 2, 3
J = 11 - I
30
HJ,I = 0.0
I = 4, 5, 6; J = 1, 2
31
RETURN

FIG. 17.

SUBROUTINE INOBS

THIS SUBROUTINE READS ALL THE OBSERVATION CARDS,CHECKS FOR ANY DATA ERRORS AND STORES ALL ACCEPTED CARDS ON A DISK.

VARIABLE	EQUA	REF	DEFINITION
ERASD(1)			STORAGE CELL
ERASE(1-3)			INPUT CELLS FOR AZIMUTH OR RIGHT ASCENSION
ERASE(5)			INPUT CELL FOR RANGE RATE
ERASE(6)			INPUT CELL FOR ELEVATION RATE
ERASE(7)			INPUT CELL FOR AZIMUTH RATE
ERASE(8)			INPUT CELL FOR RANGE ACCELERATION
MERASE(1)			INPUT CELL FOR SATELLITE NUMBER OR =1,ALL OBSERVATION CARDS WERE NOT IN ERROR. =-1,ALL OBSERVATIONCARDS WERE REJECTED BE- CAUSE OF ERRORS.
MERASE(5)			INPUT CELL FOR ELEVATION OR DECLINATION

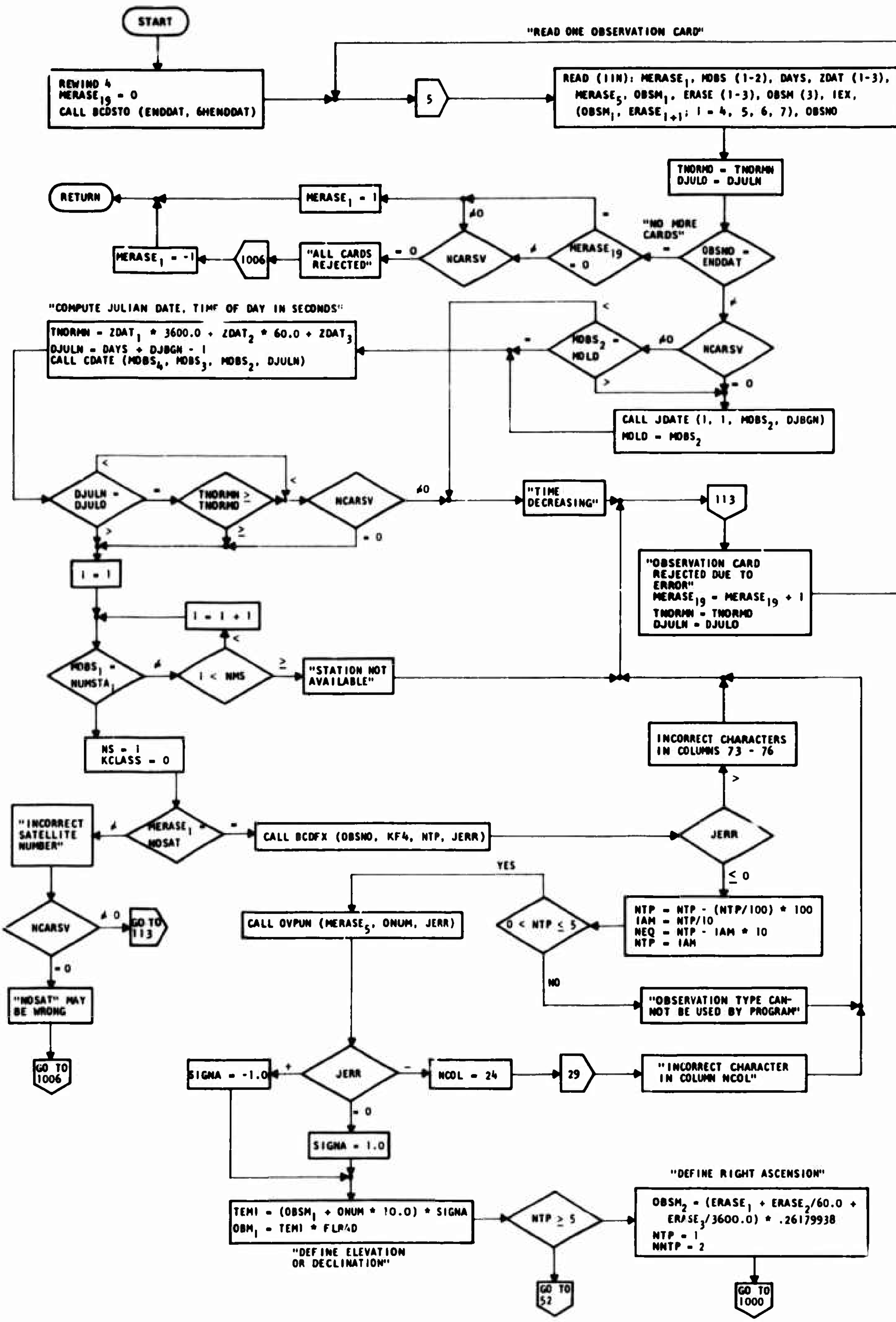
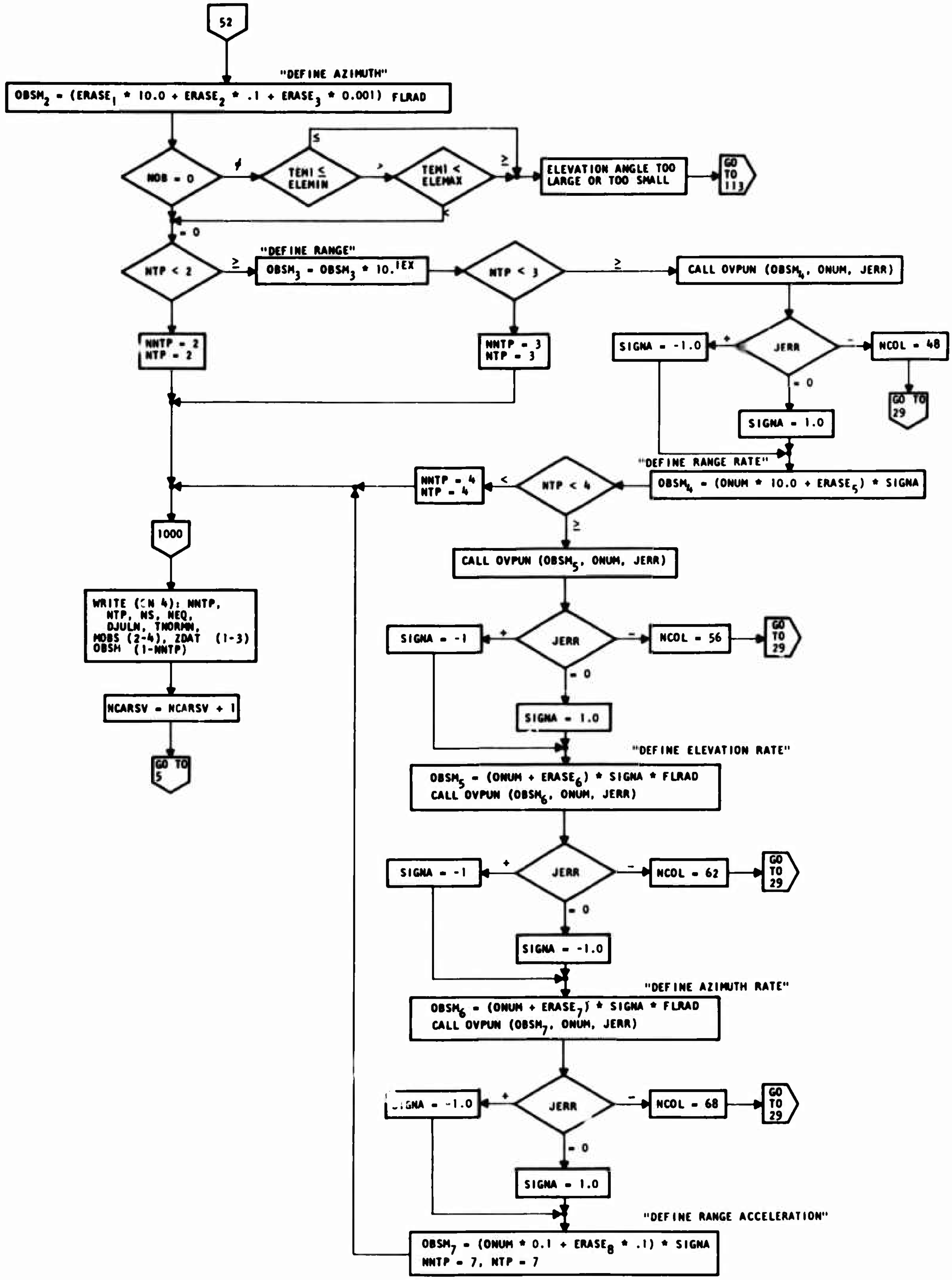

START
REWIND 4
MERASE19 = 0
CALL BCDSTO (ENDDAT, 6HENDDAT)
"READ ONE OBSERVATION CARD"
5
READ (IIN): MERASE1, MOBS (1-2), DAYS, ZDAT (1-3), MERASE5, OBSM1, ERASE (1-3), OBSM (3), IEX, (OBSMI, ERASEI+1; I = 4, 5, 6, 7), OBSNO
TNORMO = TNORMN
DJULO = DJULN
RETURN
MERASE1 = 1
"NO MORE CARDS"
OBSNO = ENDDAT
MERASE19 = 0
NCARSV
"ALL CARDS REJECTED"
1006
MERASE1 = -1
"COMPUTE JULIAN DATE, TIME OF DAY IN SECONDS"
TNORMN = ZDAT1 * 3600.0 + ZDAT2 * 60.0 + ZDAT3
DJULN = DAYS + DJBGN - 1
CALL CDATE (MOBS4, MOBS3, MOBS2, DJULN)
MOBS2 = MOLD
CALL JDATE (1, 1, MOBS2, DJBGN)
MOLD = MOBS2
DJULN = DJULO
TNORMN ≥ TNORMO
"TIME DECREASING"
113
"OBSERVATION CARD REJECTED DUE TO ERROR"
MERASE19 = MERASE19 + 1
TNORMN = TNORMO
DJULN = DJULO
I = 1
I = I + 1
MOBSI = NUMSTAI
I < NMS
"STATION NOT AVAILABLE"
NS = I
KCLASS = 0
INCORRECT CHARACTERS IN COLUMNS 73 - 76
"INCORRECT SATELLITE NUMBER"
MERASE1 = NOSAT
CALL BCDFX (OBSNO, KF4, NTP, JERR)
JERR
YES
NO
CALL OVPUN (MERASE5, ONUM, JERR)
0 < NTP ≤ 5
NTP = NTP - (NTP/100) * 100
IAM = NTP/10
NEQ = NTP - IAM * 10
NTP = IAM
GO TO 113
"NOSAT" MAY BE WRONG
GO TO 1006
"OBSERVATION TYPE CANNOT BE USED BY PROGRAM"
SIGNA = -1.0
NCOL = 24
29
"INCORRECT CHARACTER IN COLUMN NCOL"
SIGNA = 1.0
TEMI = (OBSMI + ONUM * 10.0) * SIGNA
OBMI = TEMI * FLR4D
"DEFINE ELEVATION OR DECLINATION"
NTP ≥ 5
"DEFINE RIGHT ASCENSION"
OBSM2 = (ERASE1 + ERASE2/60.0 + ERASE3/3600.0) * .26179938
NTP = 1
NNTP = 2
GO TO 52
GO TO 1000

FIG. 18.



52
"DEFINE AZIMUTH"
OBSM2 = (ERASE1 * 10.0 + ERASE2 * .1 + ERASE3 * 0.001) FLRAD
NOB = 0
TEMI ≤ ELEMIN
TEMI < ELEMAX
ELEVATION ANGLE TOO LARGE OR TOO SMALL
GO TO 113
NTP < 2
"DEFINE RANGE"
OBSM3 = OBSM3 * 10.IEX
NTP < 3
CALL OVPUN (OBSM4, ONUM, JERR)
NNTP = 2 NTP = 2
NNTP = 3 NTP = 3
SIGNA = -1.0
JERR
NCOL = 48
GO TO 29
SIGNA = 1.0
"DEFINE RANGE RATE"
OBSM4 = (ONUM * 10.0 + ERASE5) * SIGNA
NTP < 4
NNTP = 4 NTP = 4
1000
WRITE (CN 4): NNTP, NTP, NS, NEQ, DJULN, THORMN, MOBS (2-4), ZDAT (1-3) OBSM (1-NNTP)
NCARSV = NCARSV + 1
GO TO 5
CALL OVPUN (OBSM5, ONUM, JERR)
SIGNA = -1
JERR
NCOL = 56
GO TO 29
SIGNA = 1.0
"DEFINE ELEVATION RATE"
OBSM5 = (ONUM + ERASE6) * SIGNA * FLRAD
CALL OVPUN (OBSM6, ONUM, JERR)
SIGNA = -1
JERR
NCOL = 62
GO TO 29
SIGNA = -1.0
"DEFINE AZIMUTH RATE"
OBSM6 = (ONUM + ERASE7) * SIGNA * FLRAD
CALL OVPUN (OBSM7, ONUM, JERR)
SIGNA = -1.0
JERR
NCOL = 68
GO TO 29
SIGNA = 1.0
"DEFINE RANGE ACCELERATION"
OBSM7 = (ONUM * 0.1 + ERASE8 * .1) * SIGNA
NNTP = 7, NTP = 7

FIG. 19.

SUBROUTINE INTEG

THIS IS THE INTEGRATION SUBROUTINE

VARIABLE	EQUA	REF	DEFINITION
ERASE(2)	155A	1	DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM)
ERASE(4-6)	149A-149C	1	ACCELERATIONS $\ddot{X},\ddot{Y},\ddot{Z}$ (KM/SEC^2)
ICOUNT			ITERATION COUNTER
MERASE(1)			=-20,ALTITUDE BELOW 120.0(KM), OR EXOSPHERIC TEMPERATURE OUTSIDE OF 500°K - 2400°K RANGE.PROGRAM WILL NOT CONTINUE =1,COMPUTE HIGHER ORDER TERMS OF THE EARTH'S GRAVITATIONAL POTENTIAL FUNCTION AND THE DRAG TERM IN THE DIFFERENTIAL EQUATION SUBROUTINE
TEMP(6)			INTERMEDIATE VARIABLES

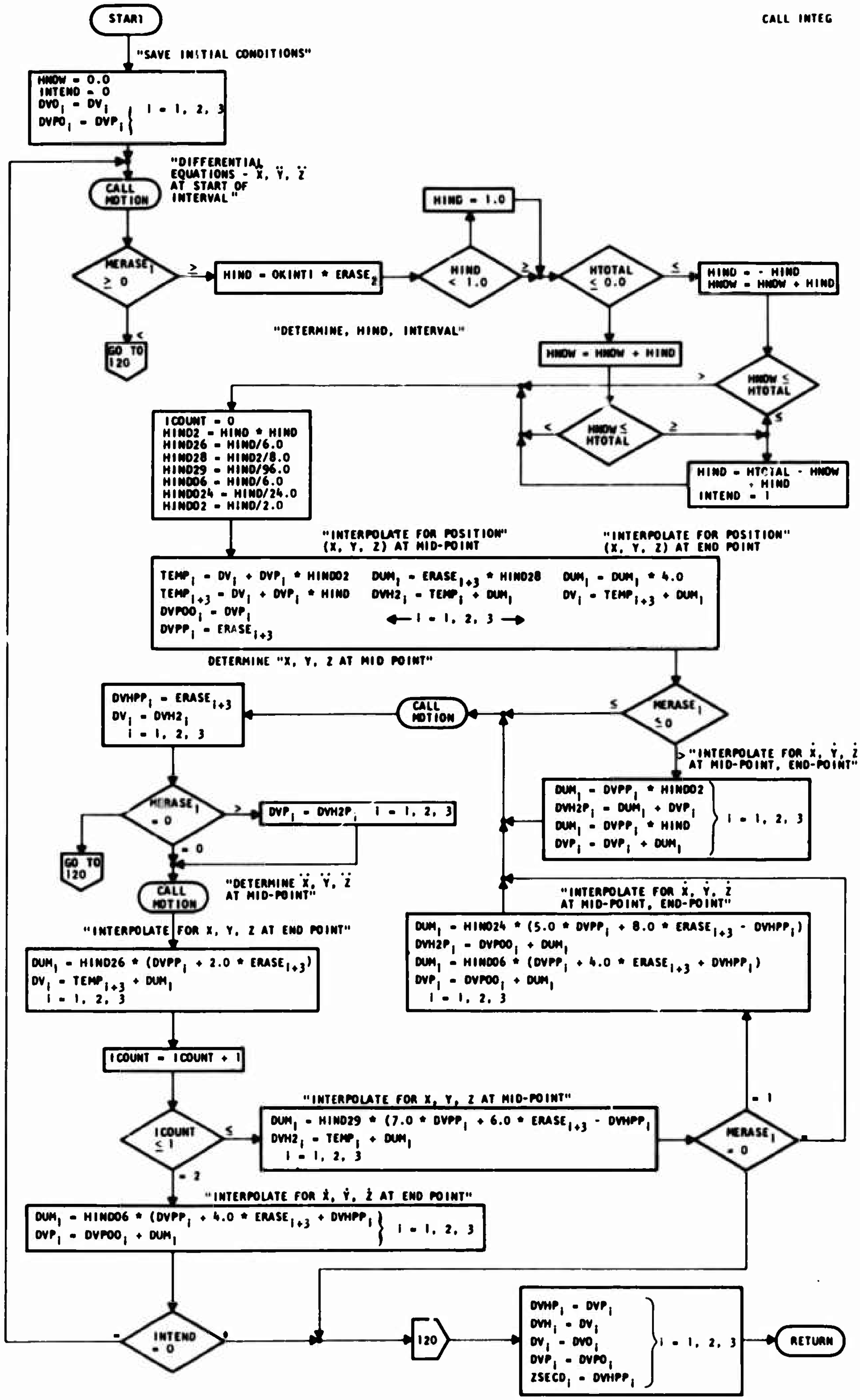
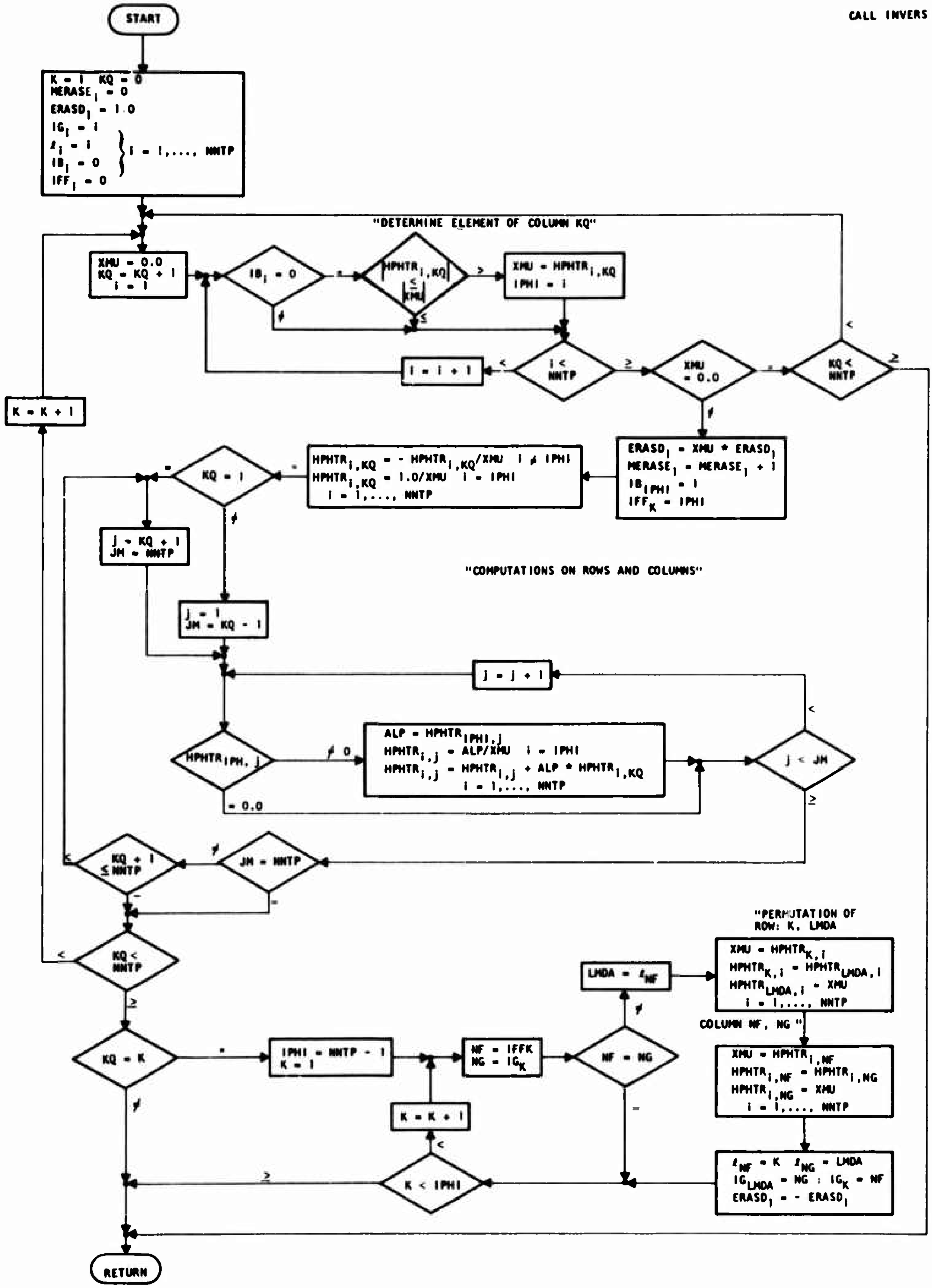

START
CALL INTEG
"SAVE INITIAL CONDITIONS"
HNOW = 0.0
INTEND = 0
DVO_I = DV_I
DVPO_I = DVP_I
I = 1, 2, 3
"DIFFERENTIAL EQUATIONS - Ẍ, Ÿ, Z̈ AT START OF INTERVAL"
CALL MOTION
MERASE_1 ≥ 0
HIND = OKINTI * ERASE_2
GO TO 120
HIND = 1.0
HIND < 1.0
HTOTAL ≤ 0.0
HIND = - HIND
HNOW = HNOW + HIND
"DETERMINE, HIND, INTERVAL"
HNOW = HNOW + HIND
HNOW ≤ HTOTAL
HNOW ≤ HTOTAL
HIND = HTOTAL - HNOW + HIND
INTEND = 1
ICOUNT = 0
HIND2 = HIND * HIND
HIND26 = HIND/6.0
HIND28 = HIND2/8.0
HIND29 = HIND/96.0
HIND06 = HIND/6.0
HIND024 = HIND/24.0
HIND02 = HIND/2.0
"INTERPOLATE FOR POSITION" (X, Y, Z) AT MID-POINT
"INTERPOLATE FOR POSITION" (X, Y, Z) AT END POINT
TEMP_I = DV_I + DVP_I * HIND02
TEMP_I+3 = DV_I + DVP_I * HIND
DVPOO_I = DVP_I
DVPP_I = ERASE_I+3
DUM_I = ERASE_I+3 * HIND28
DVH2_I = TEMP_I + DUM_I
I = 1, 2, 3
DUM_I = DUM_I * 4.0
DV_I = TEMP_I+3 + DUM_I
DETERMINE "X, Y, Z AT MID POINT"
DVHPP_I = ERASE_I+3
DV_I = DVH2_I
I = 1, 2, 3
CALL MOTION
MERASE_I ≤ 0
"INTERPOLATE FOR Ẋ, Ẏ, Ż AT MID-POINT, END-POINT"
DUM_I = DVPP_I * HIND02
DVH2P_I = DUM_I + DVP_I
DUM_I = DVPP_I * HIND
DVP_I = DVP_I + DUM_I
I = 1, 2, 3
MERASE_I = 0
DVP_I = DVH2P_I   I = 1, 2, 3
GO TO 120
CALL MOTION
"DETERMINE Ẍ, Ÿ, Z̈ AT MID-POINT"
"INTERPOLATE FOR Ẋ, Ẏ, Ż AT MID-POINT, END-POINT"
DUM_I = HIND24 * (5.0 * DVPP_I + 8.0 * ERASE_I+3 - DVHPP_I)
DVH2P_I = DVPOO_I + DUM_I
DUM_I = HIND06 * (DVPP_I + 4.0 * ERASE_I+3 + DVHPP_I)
DVP_I = DVPOO_I + DUM_I
I = 1, 2, 3
"INTERPOLATE FOR X, Y, Z AT END POINT"
DUM_I = HIND26 * (DVPP_I + 2.0 * ERASE_I+3)
DV_I = TEMP_I+3 + DUM_I
I = 1, 2, 3
ICOUNT = ICOUNT + 1
"INTERPOLATE FOR X, Y, Z AT MID-POINT"
ICOUNT ≤ 1
DUM_I = HIND29 * (7.0 * DVPP_I + 6.0 * ERASE_I+3 - DVHPP_I)
DVH2_I = TEMP_I + DUM_I
I = 1, 2, 3
MERASE_I = 0
"INTERPOLATE FOR Ẋ, Ẏ, Ż AT END POINT"
DUM_I = HIND06 * (DVPP_I + 4.0 * ERASE_I+3 + DVHPP_I)
DVP_I = DVPOO_I + DUM_I
I = 1, 2, 3
INTEND = 0
120
DVHP_I = DVP_I
DVH_I = DV_I
DV_I = DVO_I
DVP_I = DVPO_I
ZSECD_I = DVHPP_I
I = 1, 2, 3
RETURN

FIG. 20.

SUBROUTINE INVERS

THIS SUBROUTINE INVERTS A MATRIX

VARIABLE	EQUA REF	DEFINITION
ERASD(1)		DETERMINANT OF HPHTR- MATRIX TO BE INVERTED
MERASE(1)		RANK OF MATRIX TO BE INVERTED
HPHTR(I,J) I=1,....,NNTP J=1,....,NNTP		MATRIX TO BE INVERTED. THE INVERSE OF HPHTR IS STORED IN HPHTR



CALL INVERS
START
"DETERMINE ELEMENT OF COLUMN KQ"
"COMPUTATIONS ON ROWS AND COLUMNS"
"PERMUTATION OF ROW: K, LMDA
COLUMN NF, NG"
RETURN

FIG. 21.

SUBROUTINE KEPLER

THE MAIN FUNCTION OF THIS SUBROUTINE IS TO COMPUTE THE PERIOD AND THE CONSTANT K (EQUATION 193, REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
ERASE(1)	A.31		COMPUTED ECCENTRICITY AT THE EPOCH OF THE INPUT ORBITAL ELEMENTS, OUTPUT

CALL KEPLER (KARG)

START

$$XWK = (DV_1^2 + DV_2^2 + DV_3^2)^{1/2}$$

$$VSQD = DVP_1^2 + DVP_2^2 + DVP_3^2$$

$$XWKP = (DV_1 * DVP_1 + DV_2 * DVP_2 + DV_3 * DVP_3)/XWK$$

$$YWKP = (VSQD - XWKP * XWKP)^{1/2}$$

$$XWYWMU = XWK * YWKP/OMU$$

$$AELIP = 1.0 - XWYWMU * YWKP$$

$$BELIP = XWYWMU * XWKP$$

$$CELIP = XWYWMU * XWYWMU * OMU$$

$$EELIP2 = AELIP^2 + BELIP^2$$

$$EELIP = (EELIP2)^{1/2}$$

$$ERASE_1 = EELIP$$

$$SMALLA = CELIP/(1.0 - EELIP2)$$

$$PERIOD = 2\pi * SMALLA * (SMALLA/OMU)^{1/2}$$

$$DTH1 = (1.0 + 2.3 * e^{-4.19 * EELIP}) * FLRAD$$

$$OKINT1 = \left(\frac{DTH1 * XWYWMU}{1.0 + EELIP}\right)$$

RETURN

FIG. 22.

SUBROUTINE MOTION

THIS SUBROUTINE COMPUTES THE EQUATIONS OF MOTION (SECTION VIII A-VIII C,REFERENCE 1. NOTE,THE TERMS INVOLVING THE TESSERAL HARMONICS ARE NOT USED IN THE PROGRAM)

VARIABLE	EQUA	REF	DEFINITION
ALTI			SATELLITE ALTITUDE (KM)
ERASE(1-8)			INTERMEDIATE VARIABLES(EQUATIONS OF MOTION)
ERASE(1)	155A	1	ERASE(2)*ERASE(2)
ERASE(2)	155A	1	DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM)
ERASE(4-6)	149A-149C	1	ACCELERATIONS $\ddot{X},\ddot{Y},\ddot{Z}$ (KM/SEC^2)
MERASE(1)			=-20,ALTITUDE BELOW 120.0(KM), OR EXOSPHERIC TEMPERATURE OUTSIDE OF 500°K - 2400°K RANGE.PROGRAM WILL NOT CONTINUE =1,COMPUTE HIGHER ORDER TERMS OF THE EARTH'S GRAVITATIONAL POTENTIAL FUNCTION AND THE DRAG TERM IN THE DIFFERENTIAL EQUATION SUBROUTINE

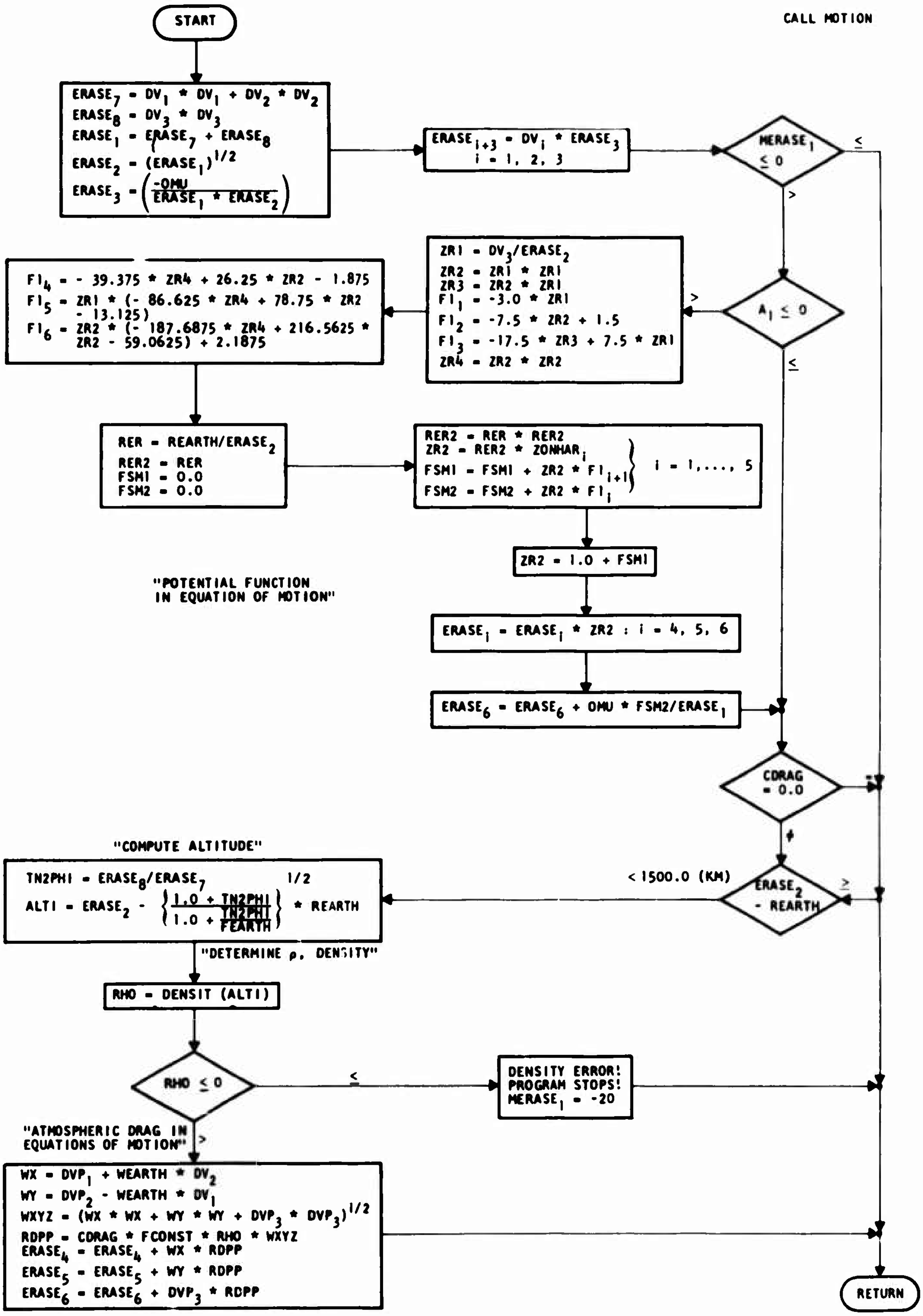

CALL MOTION
START
ERASE7 = DV1 * DV1 + DV2 * DV2
ERASE8 = DV3 * DV3
ERASE1 = ERASE7 + ERASE8
ERASE2 = (ERASE1)^1/2
ERASE3 = (-OMU / ERASE1 * ERASE2)
ERASEi+3 = DVi * ERASE3
i = 1, 2, 3
MERASE1 ≤ 0
≤
>
ZR1 = DV3/ERASE2
ZR2 = ZR1 * ZR1
ZR3 = ZR2 * ZR1
FI1 = -3.0 * ZR1
FI2 = -7.5 * ZR2 + 1.5
FI3 = -17.5 * ZR3 + 7.5 * ZR1
ZR4 = ZR2 * ZR2
A1 ≤ 0
FI4 = - 39.375 * ZR4 + 26.25 * ZR2 - 1.875
FI5 = ZR1 * (- 86.625 * ZR4 + 78.75 * ZR2 - 13.125)
FI6 = ZR2 * (- 187.6875 * ZR4 + 216.5625 * ZR2 - 59.0625) + 2.1875
RER = REARTH/ERASE2
RER2 = RER
FSM1 = 0.0
FSM2 = 0.0
RER2 = RER * RER2
ZR2 = RER2 * ZONHARi
FSM1 = FSM1 + ZR2 * FIi+1
FSM2 = FSM2 + ZR2 * FIi
i = 1,...., 5
ZR2 = 1.0 + FSM1
"POTENTIAL FUNCTION IN EQUATION OF MOTION"
ERASEi = ERASEi * ZR2 : i = 4, 5, 6
ERASE6 = ERASE6 + OMU * FSM2/ERASE1
CDRAG = 0.0
=
≠
"COMPUTE ALTITUDE"
TN2PHI = ERASE8/ERASE7
ALTI = ERASE2 - {1.0 + TN2PHI / 1.0 + TN2PHI/FEARTH}^1/2 * REARTH
< 1500.0 (KM)
ERASE2 - REARTH
≥
"DETERMINE ρ, DENSITY"
RHO = DENSIT (ALTI)
RHO ≤ 0
≤
DENSITY ERROR! PROGRAM STOPS! MERASE1 = -20
"ATMOSPHERIC DRAG IN EQUATIONS OF MOTION"
>
WX = DVP1 + WEARTH * DV2
WY = DVP2 - WEARTH * DV1
WXYZ = (WX * WX + WY * WY + DVP3 * DVP3)^1/2
RDPP = CDRAG * FCONST * RHO * WXYZ
ERASE4 = ERASE4 + WX * RDPP
ERASE5 = ERASE5 + WY * RDPP
ERASE6 = ERASE6 + DVP3 * RDPP
RETURN

FIG. 23.

SUBROUTINE NUTATI

THIS SUBROUTINE COMPUTES THE NUTATION MATRIX (EQUATION 14, REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
ERASE(1-10)	14	1	INTERMEDIATE VARIABLES

START

CALL NUTATI

$ERASE_1 = .211408 - .924222 * 10^{-3} * DJULN$
$ERASE_2 = 2.0 * ERASE_1$
$ERASE_3 = 2.247127 + .459943 * DJULN$
$ERASE_4 = 9.776679 + .03440558 * DJULN$
$ERASE_5 = 6.248291 + .01720197 * DJULN$

$ERASE_6 = SIN\ (ERASE_1)$
$ERASE_7 = SIN\ (ERASE_2)$
$ERASE_8 = SIN\ (ERASE_3)$
$ERASE_9 = SIN\ (ERASE_4)$
$ERASE_{10} = SIN\ (ERASE_5)$
$XN2_{2,1} = (-76.7 * ERASE_6 + .929 * ERASE_7 - .907 * ERASE_8 - 5.662 * ERASE_9 + .56 * ERASE_{10}) * 1.0 * 10^{-6}$
$XN2_{1,2} = - XN2_{2,1}$
$XN2_{3,1} = (-33.009 * ERASE_6 + .4 * ERASE_7 - .39 * ERASE_8 - 2.437 * ERASE_9 + .241 * ERASE_{10}) * 1.0 * 10^{-6}$
$XN2_{1,3} = - XN2_{3,1}$
$XN2_{3,2} = (44.654 * COS\ (ERASE_1) - .438 * COS\ (ERASE_2) + .428 * COS\ (ERASE_3) + 2.676 * COS\ (ERASE_4)) * 1.0 * 10^{-6}$
$XN2_{2,3} = - XN2_{3,2}$

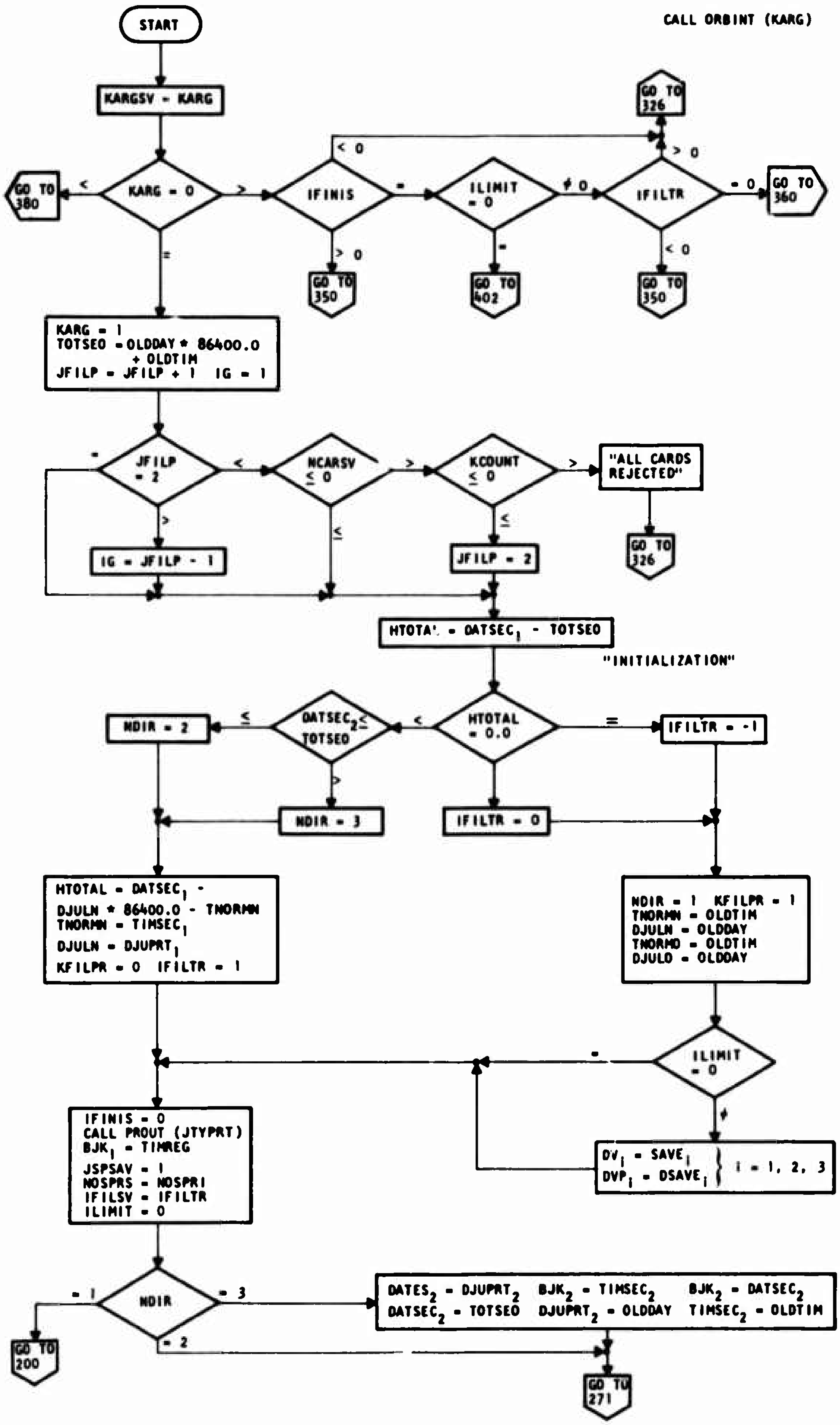
RETURN

FIG. 24.

SUBROUTINE ORBINT

THE MAIN FUNCTION OF THIS SUBROUTINE IS TO DETERMINE THE PRINT TIME OF THE EPHEMERIS, TO INTERCONNECT THE FILTERING AND EPHEMERIS COMPUTATION, AND TO EXECUTE THE SMOOTHING OPTION.

VARIABLE	EQUA REF	DEFINITION
DIAG(6,6)	A.10	INTERMEDIATE MATRIX
ERASE(1-12)		INTERMEDIATE VARIABLES
ERASE(1-6)	A.11	CORRECTION IN POSITION AND VELOCITY DUE TO SMOOTHING. OR DIFFERENCES BETWEEN STORED AND INTEGRATED VALUES IN POSITION AND VELOCITY
H(6,6)		STORAGE CELLS USED AS A MATRIX
HPHTR(6,6)	A.10, A.11	MATRIX TO BE INVERTED OR ITS INVERSE
MERASE(1)		=-20, ALTITUDE BELOW 120.0(KM), OR EXOSPHERIC TEMPERATURE OUTSIDE OF 500°K - 2400°K RANGE. PROGRAM WILL NOT CONTINUE =1, COMPUTE HIGHER ORDER TERMS OF THE EARTH'S GRAVITATIONAL POTENTIAL FUNCTION AND THE DRAG TERM IN THE DIFFERENTIAL EQUATION SUBROUTINE
SMATS(6,6)	A.11	INVERSE OF THE MATRIX



CALL ORBINT (KARG)
START
KARGSV = KARG
KARG = 0
GO TO 380
GO TO 326
IFINIS
ILIMIT = 0
IFILTR
GO TO 360
GO TO 350
GO TO 402
GO TO 350
KARG = 1
TOTSEO = OLDDAY * 86400.0 + OLDTIM
JFILP = JFILP + 1 IG = 1
JFILP = 2
NCARSV ≤ 0
KCOUNT ≤ 0
"ALL CARDS REJECTED"
GO TO 326
IG = JFILP - 1
JFILP = 2
HTOTAL = DATSEC₁ - TOTSEO
"INITIALIZATION"
NDIR = 2
DATSEC₂ ≤ TOTSEO
HTOTAL = 0.0
IFILTR = -1
NDIR = 3
IFILTR = 0
HTOTAL = DATSEC₁ - DJULN * 86400.0 - TNORMN
TNORMN = TIMSEC₁
DJULN = DJUPRT₁
KFILPR = 0 IFILTR = 1
NDIR = 1 KFILPR = 1
TNORMN = OLDTIM
DJULN = OLDDAY
TNORMO = OLDTIM
DJULO = OLDDAY
ILIMIT = 0
IFINIS = 0
CALL PROUT (JTYPRT)
BJK₁ = TIMREG
JSPSAV = 1
NOSPRS = NOSPRI
IFILSV = IFILTR
ILIMIT = 0
DV₁ = SAVE₁
DVP₁ = DSAVE₁
i = 1, 2, 3
NDIR
DATES₂ = DJUPRT₂ BJK₂ = TIMSEC₂ BJK₂ = DATSEC₂
DATSEC₂ = TOTSEO DJUPRT₂ = OLDDAY TIMSEC₂ = OLDTIM
GO TO 200
GO TO 271

FIG. 25.

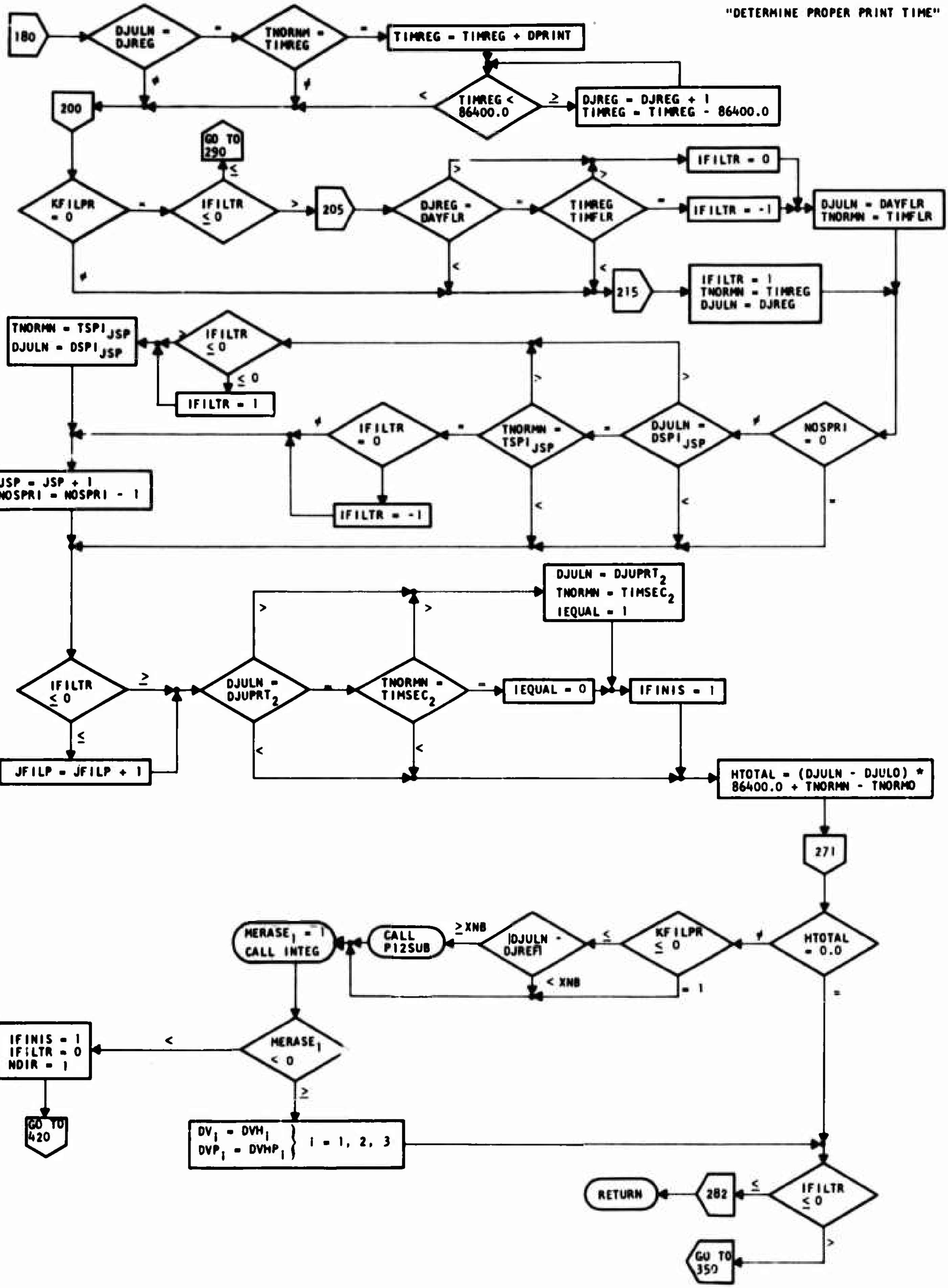

"DETERMINE PROPER PRINT TIME"
180
DJULN = DJREG
TNORMN = TIMREG
TIMREG = TIMREG + DPRINT
TIMREG < 86400.0
DJREG = DJREG + 1
TIMREG = TIMREG - 86400.0
200
GO TO 290
KFILPR = 0
IFILTR ≤ 0
205
DJREG = DAYFLR
TIMREG = TIMFLR
IFILTR = 0
IFILTR = -1
DJULN = DAYFLR
TNORMN = TIMFLR
215
IFILTR = 1
TNORMN = TIMREG
DJULN = DJREG
TNORMN = TSPI JSP
DJULN = DSPI JSP
IFILTR ≤ 0
IFILTR = 1
IFILTR = 0
TNORMN = TSPI JSP
DJULN = DSPI JSP
NOSPRI = 0
JSP = JSP + 1
NOSPRI = NOSPRI - 1
IFILTR = -1
DJULN = DJUPRT2
TNORMN = TIMSEC2
IEQUAL = 1
IFILTR ≤ 0
DJULN = DJUPRT2
TNORMN = TIMSEC2
IEQUAL = 0
IFINIS = 1
JFILP = JFILP + 1
HTOTAL = (DJULN - DJULO) * 86400.0 + TNORMN - TNORMO
271
MERASEI = 1
CALL INTEG
CALL P12SUB
|DJULN - DJREF|
≥ XNB
< XNB
KFILPR ≤ 0
HTOTAL = 0.0
IFINIS = 1
IFILTR = 0
NDIR = 1
MERASEI < 0
GO TO 420
DVI = DVHI
DVPI = DVHPI
I = 1, 2, 3
RETURN
282
IFILTR ≤ 0
GO TO 350

FIG. 26.

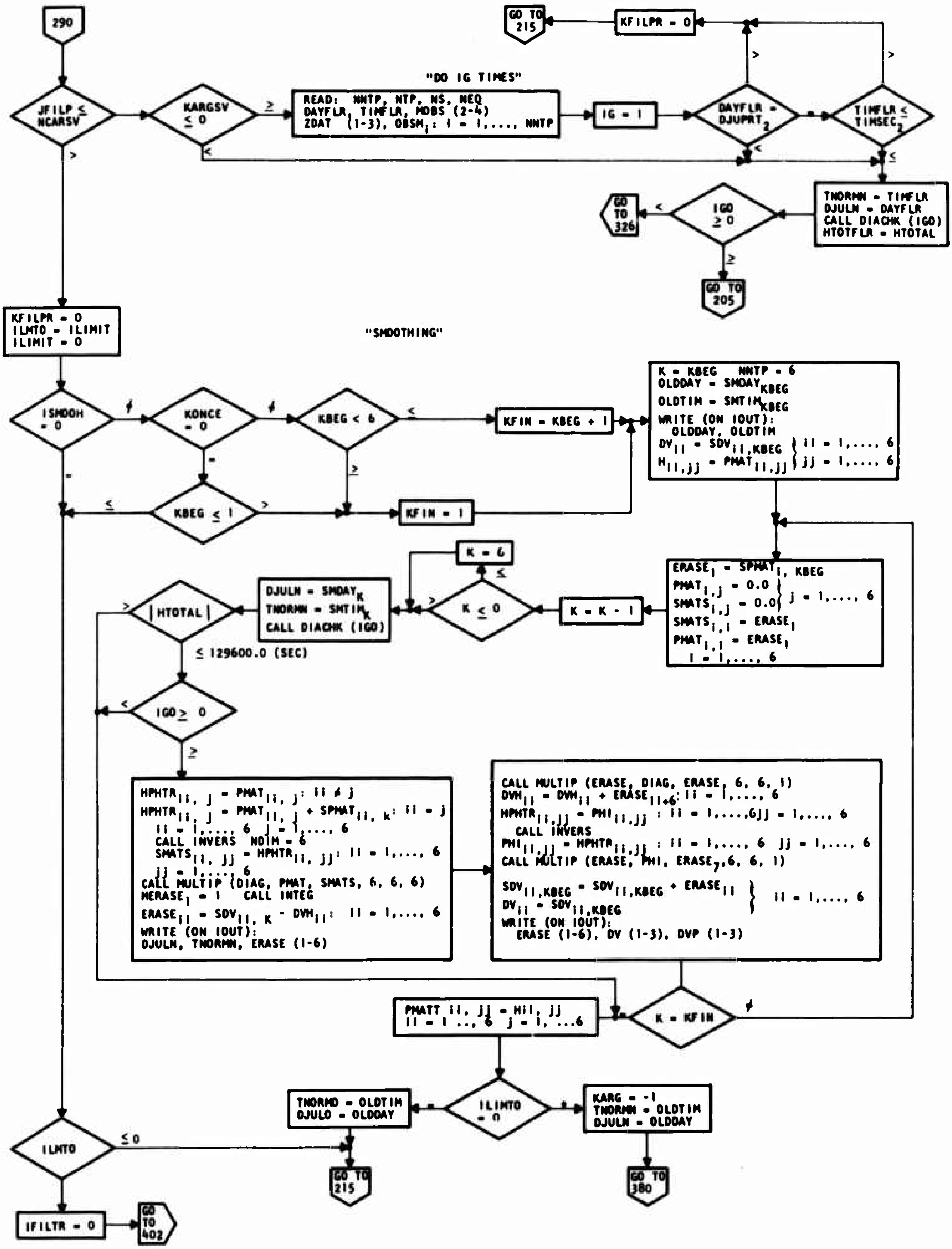
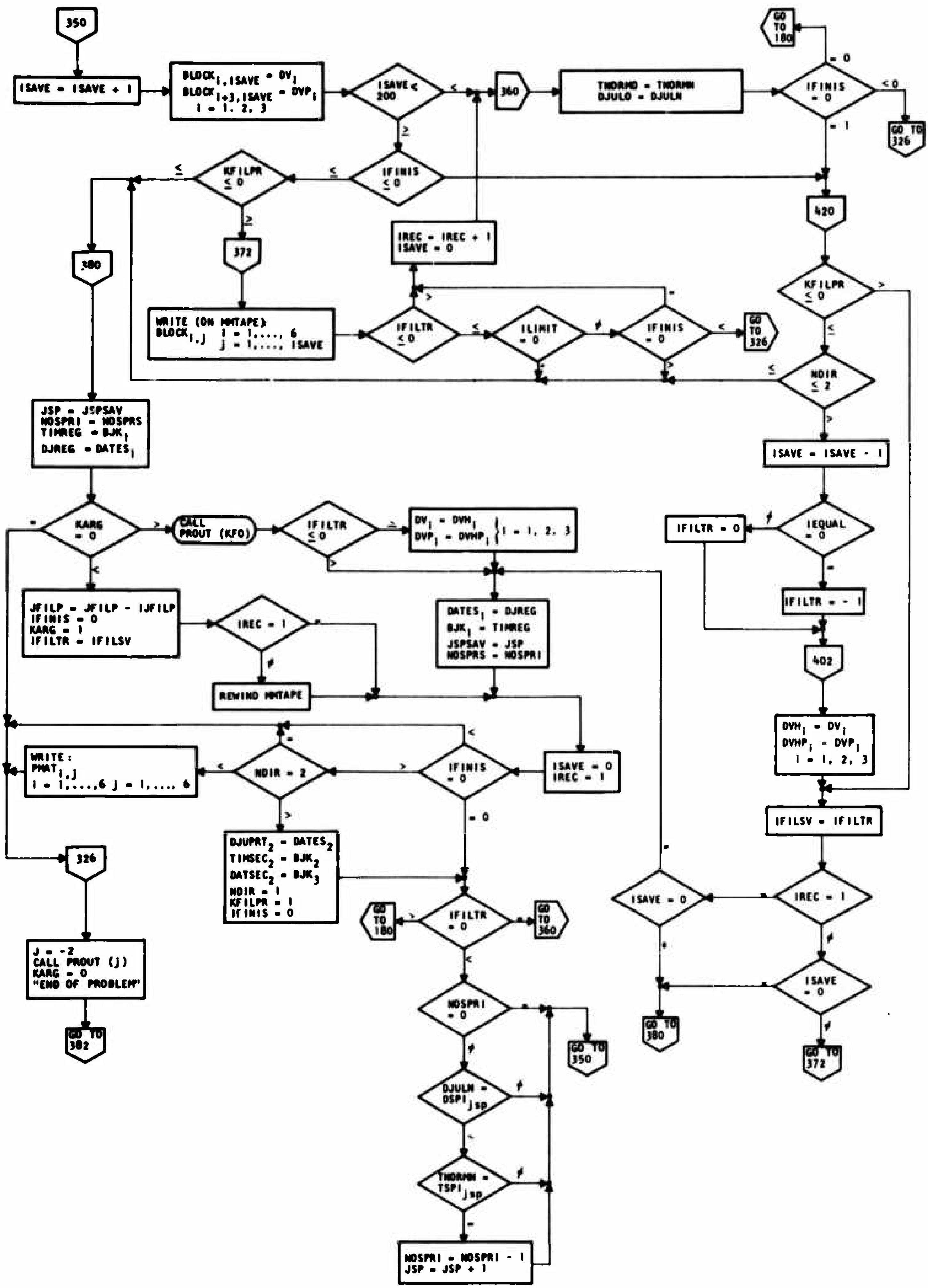

290
JFILP ≤ NCARSV
KARGSV ≤ 0
"DO IG TIMES"
READ: NNTP, NTP, NS, NEQ
DAYFLR, TIMFLR, MOBS (2-4)
ZDAT (1-3), OBSM$_i$: i = 1,...., NNTP
IG = 1
DAYFLR - DJUPRT$_2$
TIMFLR ≤ TIMSEC$_2$
KFILPR = 0
GO TO 215
TNORMN = TIMFLR
DJULN = DAYFLR
CALL DIACHK (IGO)
HTOTFLR = HTOTAL
IGO ≥ 0
GO TO 326
GO TO 205
KFILPR = 0
ILMTO = ILIMIT
ILIMIT = 0
"SMOOTHING"
ISMOOH = 0
KONCE = 0
KBEG < 6
KFIN = KBEG + 1
K = KBEG NNTP = 6
OLDDAY = SMDAY$_{KBEG}$
OLDTIM = SMTIM$_{KBEG}$
WRITE (ON IOUT): OLDDAY, OLDTIM
DV$_{ii}$ = SDV$_{ii,KBEG}$ ii = 1,...., 6
H$_{ii,jj}$ = PMAT$_{ii,jj}$ jj = 1,...., 6
KBEG ≤ 1
KFIN = 1
K = 6
K ≤ 0
K = K - 1
ERASE$_i$ = SPMAT$_{i, KBEG}$
PMAT$_{i,j}$ = 0.0
SMATS$_{i,j}$ = 0.0 j = 1,...., 6
SMATS$_{i,i}$ = ERASE$_i$
PMAT$_{i,i}$ = ERASE$_i$
i = 1,...., 6
DJULN = SMDAY$_K$
TNORMN = SMTIM$_K$
CALL DIACHK (IGO)
|HTOTAL|
≤ 129600.0 (SEC)
IGO ≥ 0
HPHTR$_{ii, j}$ = PMAT$_{ii, j}$: ii ≠ j
HPHTR$_{ii, j}$ = PMAT$_{ii, j}$ + SPMAT$_{ii, k}$: ii = j
ii = 1,...., 6 j = 1,...., 6
CALL INVERS NDIM = 6
SMATS$_{ii, jj}$ = HPHTR$_{ii, jj}$: ii = 1,...., 6
jj = 1,...., 6
CALL MULTIP (DIAG, PMAT, SMATS, 6, 6, 6)
MERASE$_i$ = 1 CALL INTEG
ERASE$_{ii}$ = SDV$_{ii, K}$ - DVH$_{ii}$: ii = 1,...., 6
WRITE (ON IOUT):
DJULN, TNORMN, ERASE (1-6)
CALL MULTIP (ERASE, DIAG, ERASE, 6, 6, 1)
DVH$_{ii}$ = DVH$_{ii}$ + ERASE$_{ii+6}$: ii = 1,...., 6
HPHTR$_{ii,jj}$ = PHI$_{ii,jj}$: ii = 1,....,6 jj = 1,...., 6
CALL INVERS
PHI$_{ii,jj}$ = HPHTR$_{ii,jj}$: ii = 1,...., 6 jj = 1,...., 6
CALL MULTIP (ERASE, PHI, ERASE$_7$, 6, 6, 1)
SDV$_{ii,KBEG}$ = SDV$_{ii,KBEG}$ + ERASE$_{ii}$
DV$_{ii}$ = SDV$_{ii,KBEG}$ ii = 1,...., 6
WRITE (ON IOUT):
ERASE (1-6), DV (1-3), DVP (1-3)
K = KFIN
PMATT ii, jj = Hii, jj
ii = 1 ..., 6 j = 1, ...6
ILMTO = 0
TNORMD = OLDTIM
DJULO = OLDDAY
KARG = -1
TNORMN = OLDTIM
DJULN = OLDDAY
ILMTO
≤ 0
GO TO 215
GO TO 380
IFILTR = 0
GO TO 402

FIG. 27.



350
ISAVE = ISAVE + 1
BLOCK$_{i,ISAVE}$ = DV$_i$
BLOCK$_{i+3,ISAVE}$ = DVP$_i$
i = 1, 2, 3
ISAVE < 200
360
THORMD = THORMN
DJULO = DJULN
IFINIS = 0
GO TO 180
GO TO 326
IFINIS ≤ 0
KFILPR ≤ 0
372
380
IREC = IREC + 1
ISAVE = 0
420
KFILPR ≤ 0
WRITE (ON MMTAPE):
BLOCK$_{i,j}$ i = 1,...., 6
j = 1,...., ISAVE
IFILTR ≤ 0
ILIMIT = 0
IFINIS = 0
GO TO 326
NDIR ≤ 2
JSP = JSPSAV
NOSPRI = NOSPRS
TIMREG = BJK$_1$
DJREG = DATES$_1$
ISAVE = ISAVE - 1
KARG = 0
CALL PROUT (KFO)
IFILTR ≤ 0
DV$_i$ = DVH$_i$
DVP$_i$ = DVHP$_i$
i = 1, 2, 3
IFILTR = 0
IEQUAL = 0
JFILP = JFILP - IJFILP
IFINIS = 0
KARG = 1
IFILTR = IFILSV
IREC = 1
DATES$_1$ = DJREG
BJK$_1$ = TIMREG
JSPSAV = JSP
NOSPRS = NOSPRI
IFILTR = - 1
402
REWIND MMTAPE
DVH$_i$ = DV$_i$
DVHP$_i$ = DVP$_i$
i = 1, 2, 3
WRITE:
PHAT$_{i,j}$
i = 1,....,6 j = 1,...., 6
NDIR = 2
IFINIS = 0
ISAVE = 0
IREC = 1
IFILSV = IFILTR
326
DJUPRT$_2$ = DATES$_2$
TIMSEC$_2$ = BJK$_2$
DATSEC$_2$ = BJK$_3$
NDIR = 1
KFILPR = 1
IFINIS = 0
ISAVE = 0
IREC = 1
GO TO 180
IFILTR = 0
GO TO 360
J = -2
CALL PROUT (J)
KARG = 0
"END OF PROBLEM"
ISAVE = 0
GO TO 382
NOSPRI = 0
GO TO 350
GO TO 380
GO TO 372
DJULN = DSPI$_{jsp}$
THORMN = TSPI$_{jsp}$
NOSPRI = NOSPRI - 1
JSP = JSP + 1

FIG. 28.

SUBROUTINE P12SUB

THIS SUBROUTINE COMPUTES THE TRANSFORMATION MATRIX BETWEEN TWO BASIC REFERENCE SYSTEMS.(SEE EQUATION 15,REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
P12(3,3)	15	1	TRANSFORMATION MATRIX OF THE RECTANGULAR CO-ORDINATES BETWEEN TWO SYSTEMS OF ARBITRARY DATES
P2(3,3)	13	1	PRECESSION MATRIX (COMPUTED AT DJULN)

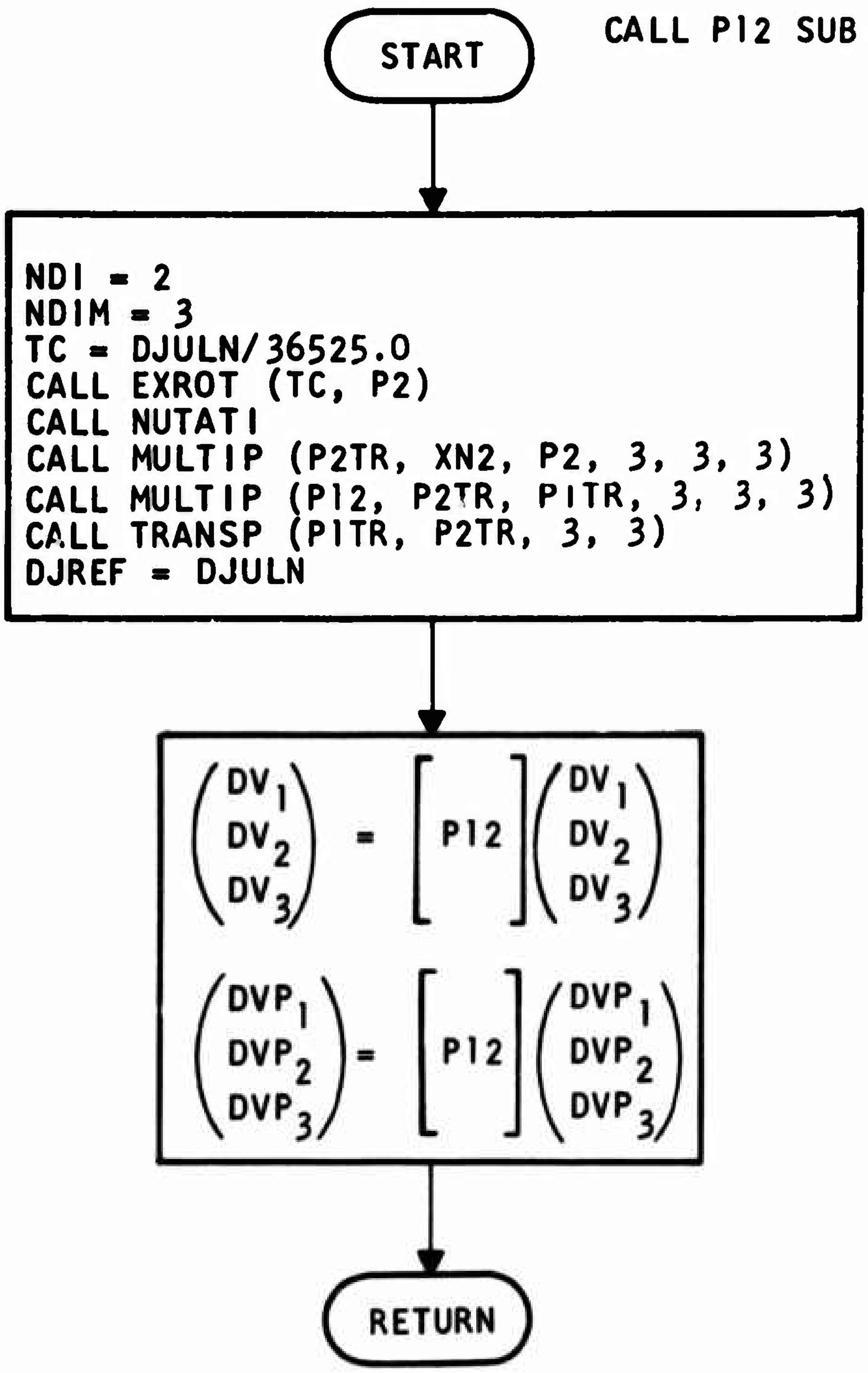

CALL P12 SUB
START
NDI = 2
NDIM = 3
TC = DJULN/36525.0
CALL EXROT (TC, P2)
CALL NUTATI
CALL MULTIP (P2TR, XN2, P2, 3, 3, 3)
CALL MULTIP (P12, P2TR, P1TR, 3, 3, 3)
CALL TRANSP (P1TR, P2TR, 3, 3)
DJREF = DJULN
$\begin{pmatrix} DV_1 \\ DV_2 \\ DV_3 \end{pmatrix} = \begin{bmatrix} P12 \end{bmatrix} \begin{pmatrix} DV_1 \\ DV_2 \\ DV_3 \end{pmatrix}$
$\begin{pmatrix} DVP_1 \\ DVP_2 \\ DVP_3 \end{pmatrix} = \begin{bmatrix} P12 \end{bmatrix} \begin{pmatrix} DVP_1 \\ DVP_2 \\ DVP_3 \end{pmatrix}$
RETURN

FIG. 29.

SUBROUTINE POSVEL

THIS SUBROUTINE CONVERTS THE CLASSICAL ELEMENTS TO POSITION AND VELOCITY COORDINATES.(APPENDIX G)

VARIABLE	EQUA	REF	DEFINITION
ERASE(1)			INTERMEDIATE VARIABLE
MERASE(1)			ITERATION COUNTER
P2(3,3)	A.56		INTERMEDIATE MATRIX
XM(2,2)	A.54,A.56		INTERMEDIATE MATRIX

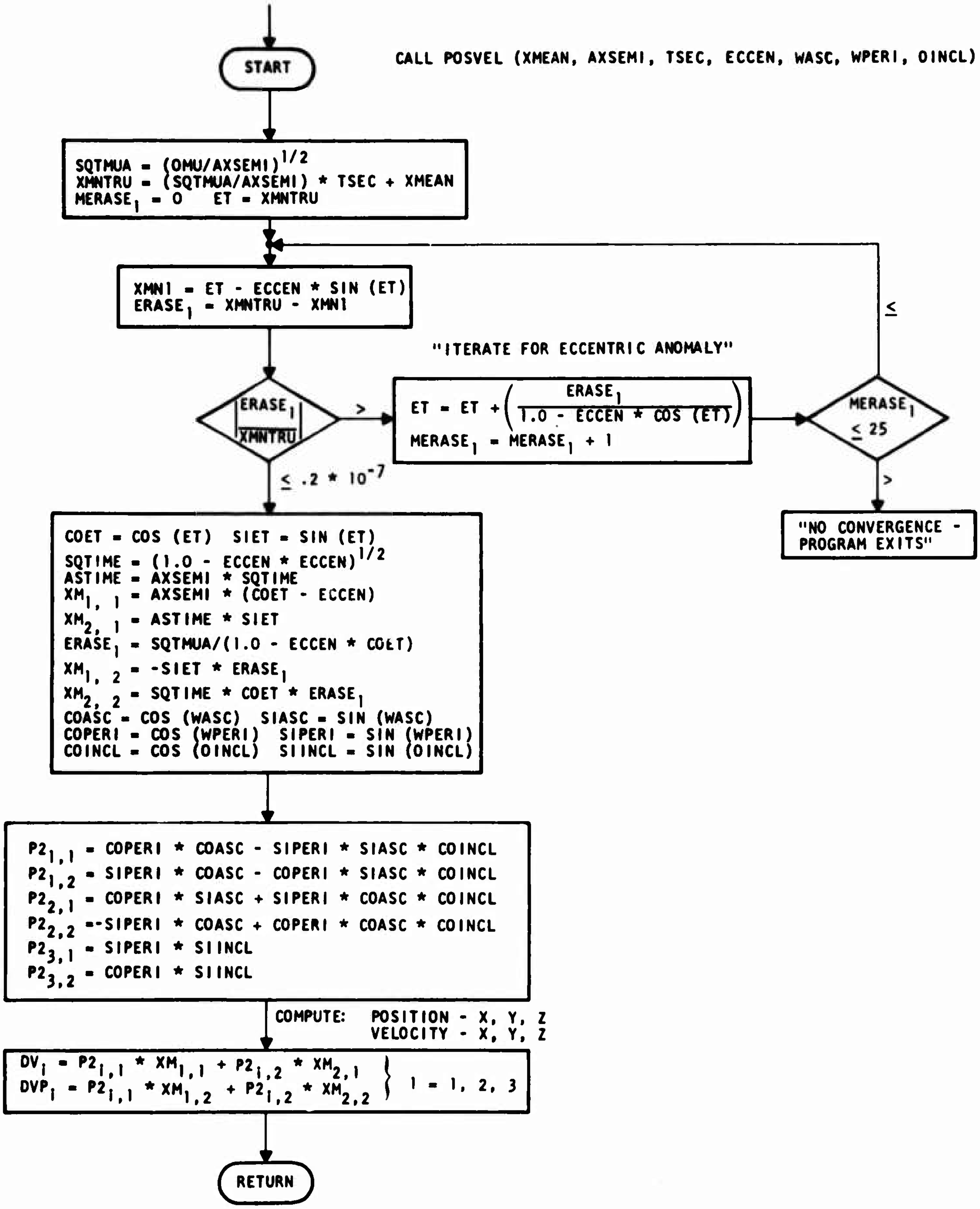

CALL POSVEL (XMEAN, AXSEMI, TSEC, ECCEN, WASC, WPERI, OINCL)
START
SQTMUA = (OMU/AXSEMI)^1/2
XMNTRU = (SQTMUA/AXSEMI) * TSEC + XMEAN
MERASE1 = 0 ET = XMNTRU
XMN1 = ET - ECCEN * SIN (ET)
ERASE1 = XMNTRU - XMN1
"ITERATE FOR ECCENTRIC ANOMALY"
|ERASE1| / |XMNTRU|
>
ET = ET + (ERASE1 / (1.0 - ECCEN * COS (ET)))
MERASE1 = MERASE1 + 1
MERASE1 ≤ 25
≤
>
"NO CONVERGENCE - PROGRAM EXITS"
≤ .2 * 10^-7
COET = COS (ET) SIET = SIN (ET)
SQTIME = (1.0 - ECCEN * ECCEN)^1/2
ASTIME = AXSEMI * SQTIME
XM1, 1 = AXSEMI * (COET - ECCEN)
XM2, 1 = ASTIME * SIET
ERASE1 = SQTMUA/(1.0 - ECCEN * COET)
XM1, 2 = -SIET * ERASE1
XM2, 2 = SQTIME * COET * ERASE1
COASC = COS (WASC) SIASC = SIN (WASC)
COPERI = COS (WPERI) SIPERI = SIN (WPERI)
COINCL = COS (OINCL) SIINCL = SIN (OINCL)
P21,1 = COPERI * COASC - SIPERI * SIASC * COINCL
P21,2 = SIPERI * COASC - COPERI * SIASC * COINCL
P22,1 = COPERI * SIASC + SIPERI * COASC * COINCL
P22,2 = -SIPERI * COASC + COPERI * COASC * COINCL
P23,1 = SIPERI * SIINCL
P23,2 = COPERI * SIINCL
COMPUTE: POSITION - X, Y, Z
VELOCITY - X, Y, Z
DVI = P2I,1 * XM1,1 + P2I,2 * XM2,1
DVPI = P2I,1 * XM1,2 + P2I,2 * XM2,2
I = 1, 2, 3
RETURN

FIG. 30.

SUBROUTINE PROUT

THIS SUBROUTINE COMPUTES THE EPHEMERIS AND STORES IT ON A BCD AND/OR BINARY TAPE.

VARIABLE	EQUA	REF	DEFINITION
ALT1	A.61		NORMALIZED SATELLITE ALTITUDE
CON(1-5)	16	1	INTERMEDIATE VARIABLES
CON(6)	17	1	INTERMEDIATE VARIABLE, $\dot{Z}$
DJULO			MODIFIED JULIAN DATE OF THE PRINT TIME
ERASD(1-10)			INTERMEDIATE VARIABLES
ERASD(4)	10	1	GREENWICH HOUR ANGLE OF THE VERNAL EQUINOX
ERASD(5)	11	1	INTERMEDIATE VARIABLE
ERASD(10)	10	1	INTERMEDIATE VARIABLE
ERASE(1-20)			INTERMEDIATE VARIABLE
ERASE(2)	A.24		DISTANCE OF THE SATELLITE FROM THE CENTER OF THE EARTH (KM)
ERASE(5)	A.25		VELOCITY SQUARED$(KM/SEC)^2$
MERASE(1)			STORAGE CELL
TNORMO			TIME OF DAY IN SECONDS CORRESPONDING TO DJULO (SEE DJULO, ABOVE)

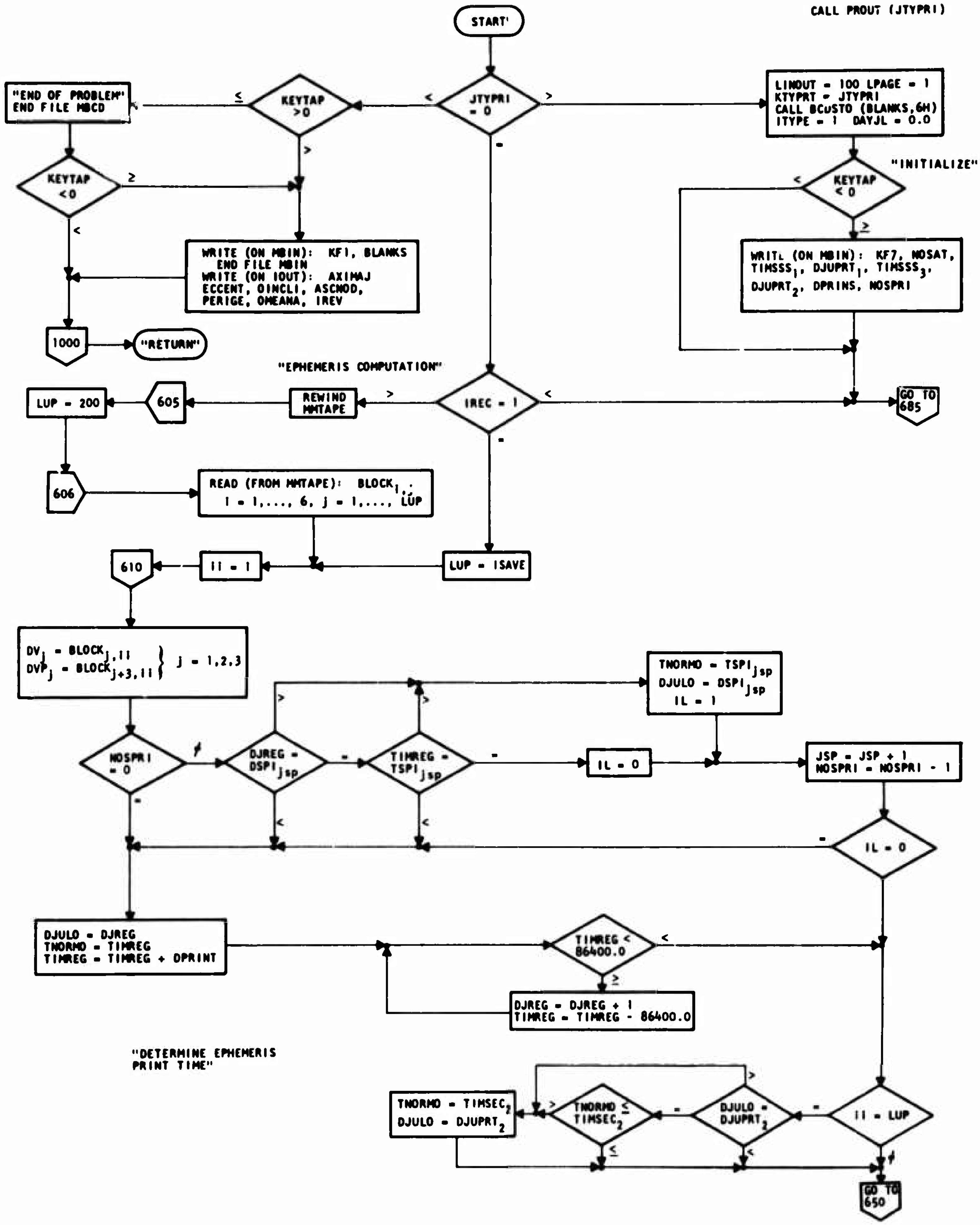

START'
CALL PROUT (JTYPRI)
JTYPRI = 0
KEYTAP >0
"END OF PROBLEM"
END FILE MBCD
LINOUT = 100 LPAGE = 1
KTYPRT = JTYPRI
CALL BCUSTO (BLANKS,6H)
ITYPE = 1 DAYJL = 0.0
"INITIALIZE"
KEYTAP <0
KEYTAP <0
WRITE (ON MBIN): KF1, BLANKS
END FILE MBIN
WRITE (ON IOUT): AXIMAJ
ECCENT, OINCLI, ASCNOD,
PERIGE, OMEANA, IREV
WRITE (ON MBIN): KF7, NOSAT, TIMSSS1, DJUPRT1, TIMSSS3, DJUPRT2, DPRINS, NOSPRI
1000
"RETURN"
"EPHEMERIS COMPUTATION"
LUP = 200
605
REWIND MMTAPE
IREC = 1
GO TO 685
606
READ (FROM MMTAPE): BLOCKi,j
i = 1,..., 6, j = 1,..., LUP
610
II = 1
LUP = ISAVE
DVj = BLOCKj,II
DVPj = BLOCKj+3,II
j = 1,2,3
TNORMO = TSPIjsp
DJULO = DSPIjsp
IL = 1
NOSPRI = 0
DJREG = DSPIjsp
TIMREG = TSPIjsp
IL = 0
JSP = JSP + 1
NOSPRI = NOSPRI - 1
IL = 0
DJULO = DJREG
TNORMO = TIMREG
TIMREG = TIMREG + DPRINT
TIMREG < 86400.0
DJREG = DJREG + 1
TIMREG = TIMREG - 86400.0
"DETERMINE EPHEMERIS PRINT TIME"
TNORMO = TIMSEC2
DJULO = DJUPRT2
TNORMO ≤ TIMSEC2
DJULO = DJUPRT2
II = LUP
GO TO 650

FIG. 31.

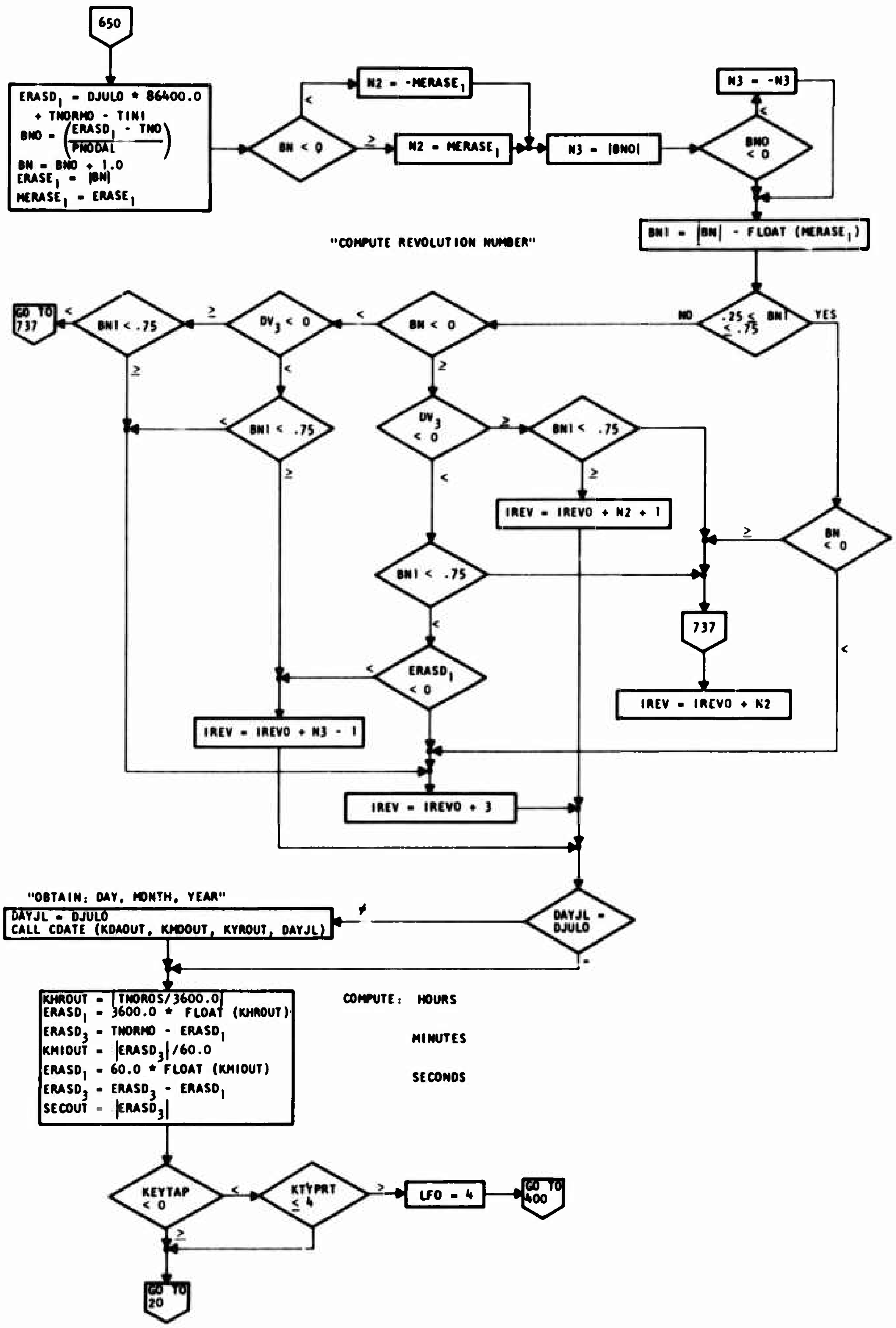

650
ERASD₁ = DJULO * 86400.0 + TNORMO - TINI
BNO = (ERASD₁ - TNO)/PNODAL
BN = BNO + 1.0
ERASE₁ = |BN|
MERASE₁ = ERASE₁
BN < 0
N2 = -MERASE₁
N2 = MERASE₁
N3 = |BNO|
BNO < 0
N3 = -N3
BNI = |BN| - FLOAT (MERASE₁)
"COMPUTE REVOLUTION NUMBER"
.25 ≤ BNI ≤ .75
NO
YES
BN < 0
DV₃ < 0
BNI < .75
GO TO 737
BNI < .75
DV₃ < 0
BNI < .75
IREV = IREVO + N2 + 1
BN < 0
BNI < .75
737
ERASD₁ < 0
IREV = IREVO + N2
IREV = IREVO + N3 - 1
IREV = IREVO + 3
"OBTAIN: DAY, MONTH, YEAR"
DAYJL = DJULO
CALL CDATE (KDAOUT, KMDOUT, KYROUT, DAYJL)
DAYJL = DJULO
KHROUT = [TNOROS/3600.0]
ERASD₁ = 3600.0 * FLOAT (KHROUT)
ERASD₃ = TNORMO - ERASD₁
KMIOUT = |ERASD₃|/60.0
ERASD₁ = 60.0 * FLOAT (KMIOUT)
ERASD₃ = ERASD₃ - ERASD₁
SECOUT = |ERASD₃|
COMPUTE: HOURS
MINUTES
SECONDS
KEYTAP < 0
KTYPRT ≤ 4
LFO = 4
GO TO 400
GO TO 20

FIG. 32.

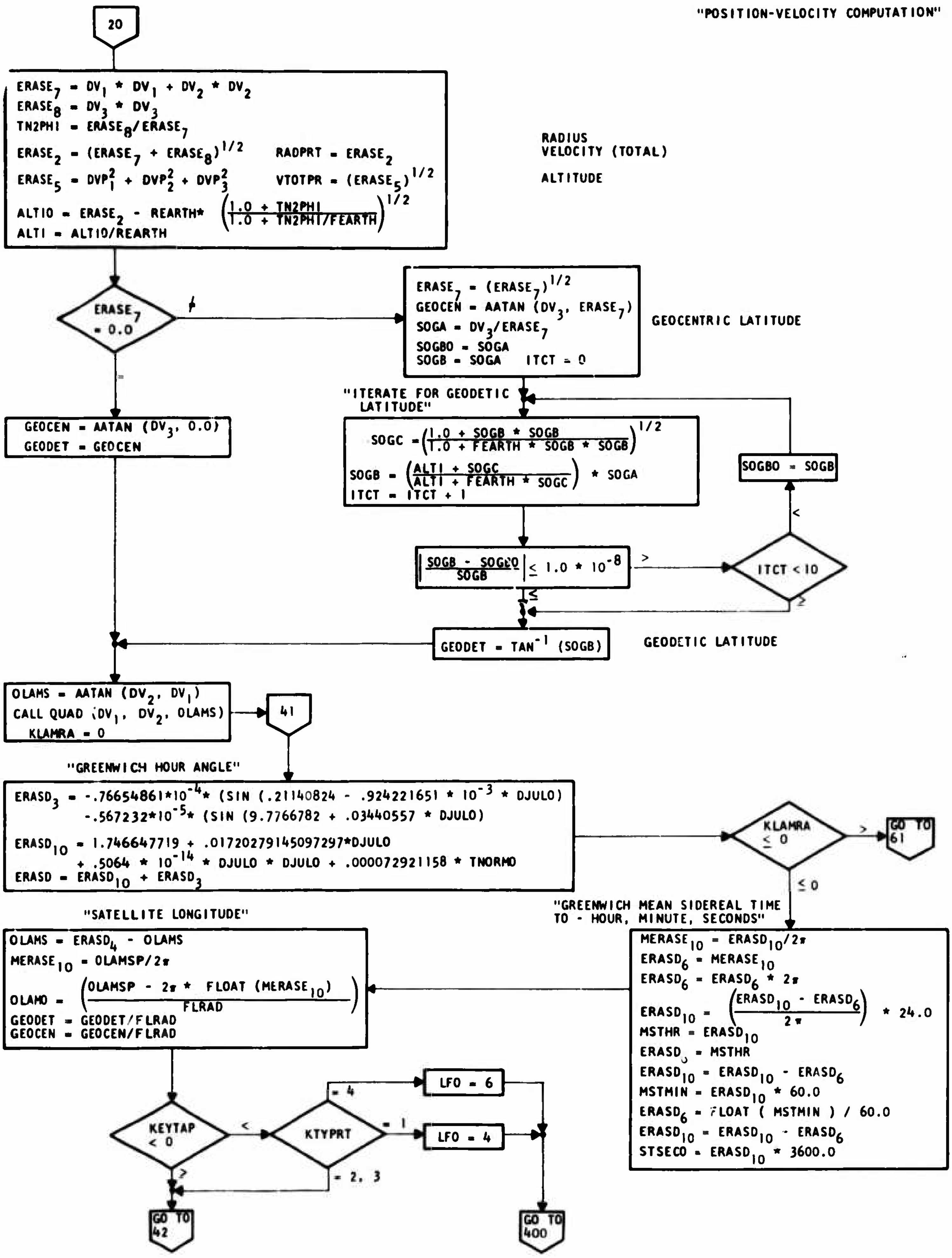
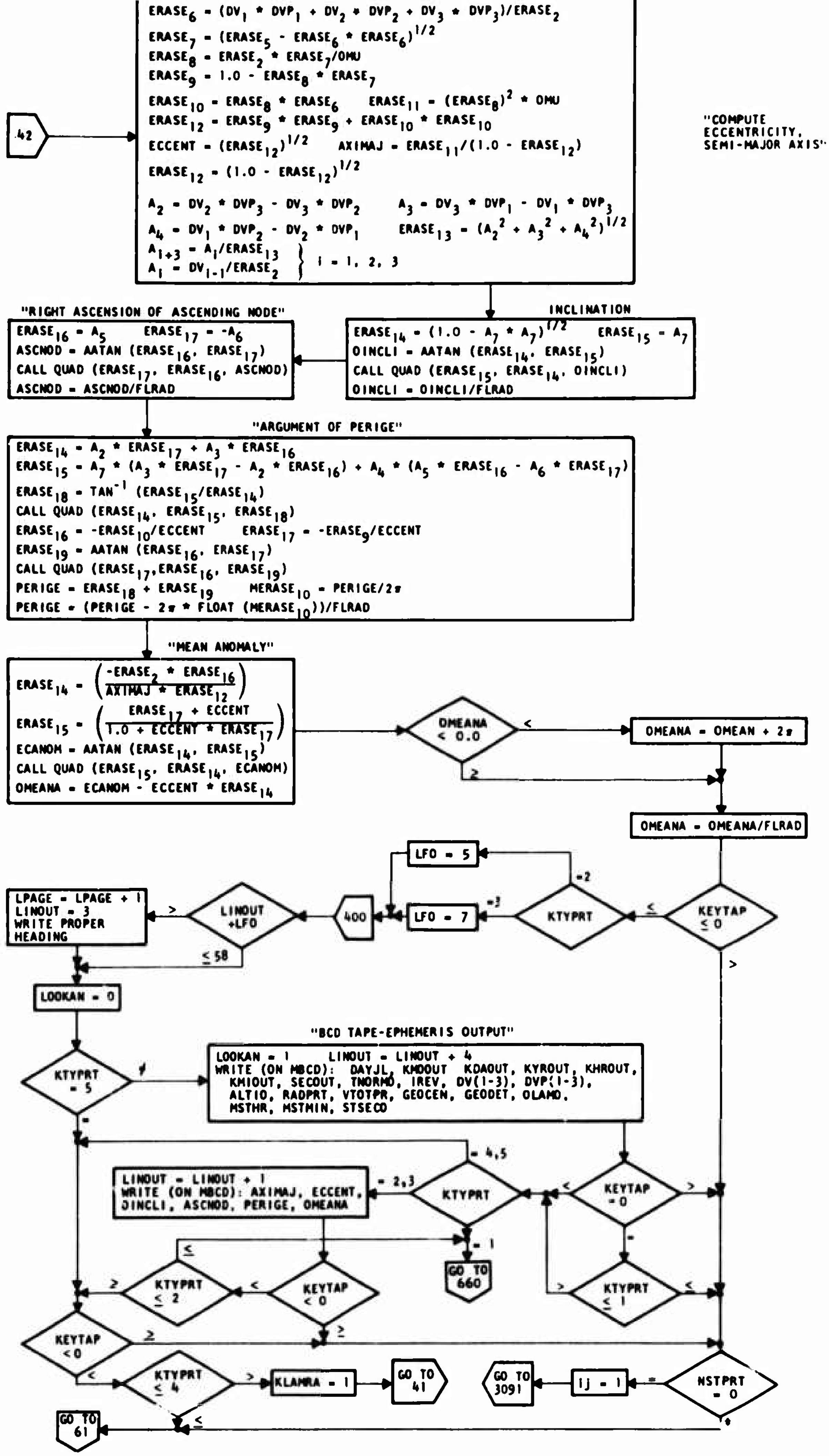
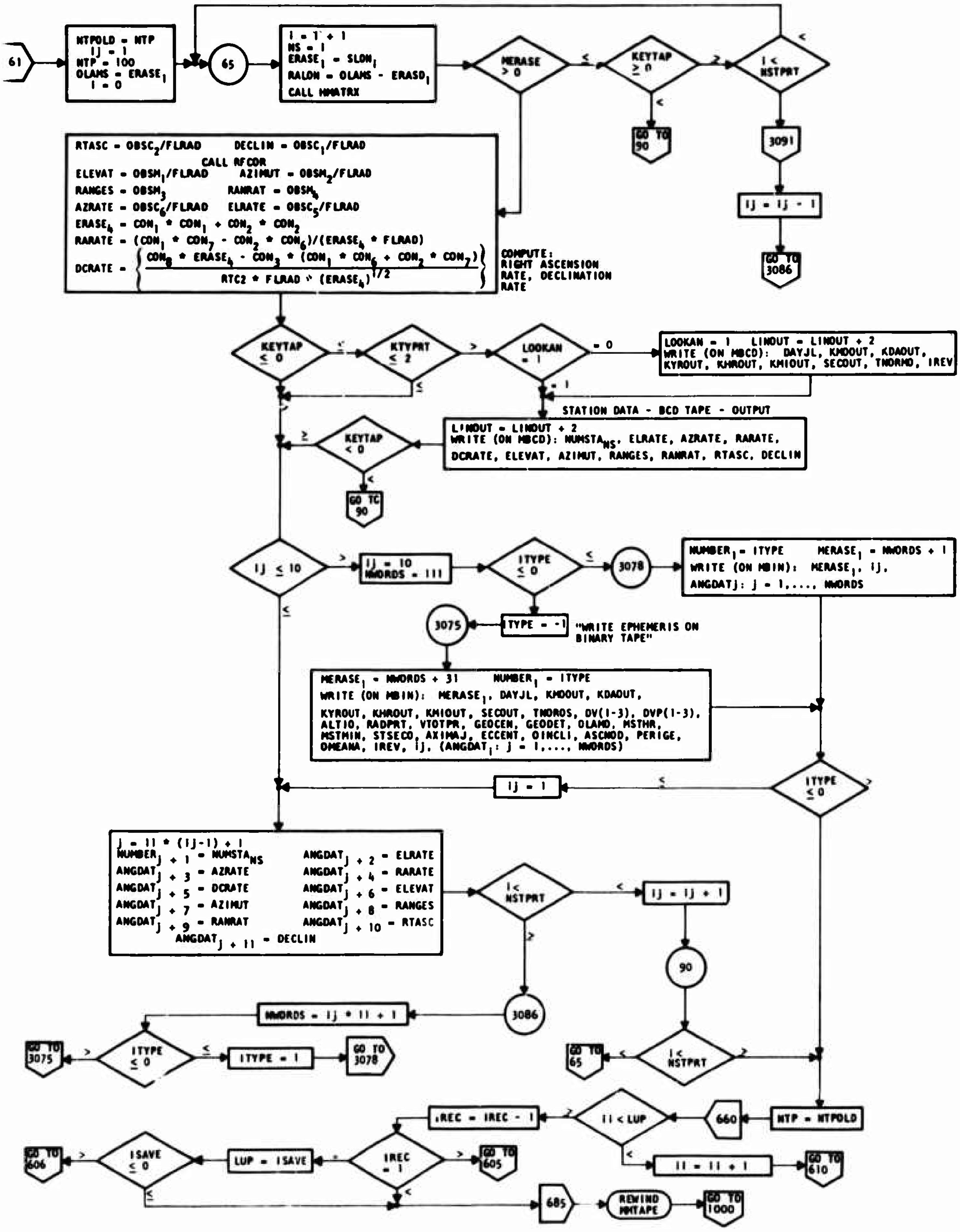

"POSITION-VELOCITY COMPUTATION"
20
ERASE7 = DV1 * DV1 + DV2 * DV2
ERASE8 = DV3 * DV3
TN2PHI = ERASE8/ERASE7
ERASE2 = (ERASE7 + ERASE8)^1/2
RADPRT = ERASE2
ERASE5 = DVP1^2 + DVP2^2 + DVP3^2
VTOTPR = (ERASE5)^1/2
ALTIO = ERASE2 - REARTH* ((1.0 + TN2PHI)/(1.0 + TN2PHI/FEARTH))^1/2
ALTI = ALTIO/REARTH
RADIUS
VELOCITY (TOTAL)
ALTITUDE
ERASE7 = 0.0
≠
=
ERASE7 = (ERASE7)^1/2
GEOCEN = AATAN (DV3, ERASE7)
SOGA = DV3/ERASE7
SOGBO = SOGA
SOGB = SOGA ITCT = 0
GEOCENTRIC LATITUDE
GEOCEN = AATAN (DV3, 0.0)
GEODET = GEOCEN
"ITERATE FOR GEODETIC LATITUDE"
SOGC = ((1.0 + SOGB * SOGB)/(1.0 + FEARTH * SOGB * SOGB))^1/2
SOGB = ((ALTI + SOGC)/(ALTI + FEARTH * SOGC)) * SOGA
ITCT = ITCT + 1
SOGBO = SOGB
<
|(SOGB - SOGBO)/SOGB| ≤ 1.0 * 10^-8
>
≤
ITCT < 10
≥
GEODET = TAN^-1 (SOGB)
GEODETIC LATITUDE
OLAMS = AATAN (DV2, DV1)
CALL QUAD (DV1, DV2, OLAMS)
KLAMRA = 0
41
"GREENWICH HOUR ANGLE"
ERASD3 = -.76654861*10^-4* (SIN (.21140824 - .924221651 * 10^-3 * DJULO)
-.567232*10^-5* (SIN (9.7766782 + .03440557 * DJULO)
ERASD10 = 1.746647719 + .01720279145097297*DJULO
+ .5064 * 10^-14 * DJULO * DJULO + .000072921158 * TNORMO
ERASD = ERASD10 + ERASD3
KLAMRA ≤ 0
>
GO TO 61
≤ 0
"GREENWICH MEAN SIDEREAL TIME TO - HOUR, MINUTE, SECONDS"
MERASE10 = ERASD10/2π
ERASD6 = MERASE10
ERASD6 = ERASD6 * 2π
ERASD10 = ((ERASD10 - ERASD6)/2π) * 24.0
MSTHR = ERASD10
ERASD6 = MSTHR
ERASD10 = ERASD10 - ERASD6
MSTMIN = ERASD10 * 60.0
ERASD6 = FLOAT (MSTMIN) / 60.0
ERASD10 = ERASD10 - ERASD6
STSECO = ERASD10 * 3600.0
"SATELLITE LONGITUDE"
OLAMS = ERASD4 - OLAMS
MERASE10 = OLAMSP/2π
OLAMO = ((OLAMSP - 2π * FLOAT (MERASE10))/FLRAD)
GEODET = GEODET/FLRAD
GEOCEN = GEOCEN/FLRAD
KEYTAP < 0
<
KTYPRT
= 4
LFO = 6
= 1
LFO = 4
= 2, 3
>
GO TO 42
GO TO 400

FIG. 33.



42
ERASE6 = (DV1 * DVP1 + DV2 * DVP2 + DV3 * DVP3)/ERASE2
ERASE7 = (ERASE5 - ERASE6 * ERASE6)1/2
ERASE8 = ERASE2 * ERASE7/OMU
ERASE9 = 1.0 - ERASE8 * ERASE7
ERASE10 = ERASE8 * ERASE6   ERASE11 = (ERASE8)2 * OMU
ERASE12 = ERASE9 * ERASE9 + ERASE10 * ERASE10
ECCENT = (ERASE12)1/2   AXIMAJ = ERASE11/(1.0 - ERASE12)
ERASE12 = (1.0 - ERASE12)1/2
A2 = DV2 * DVP3 - DV3 * DVP2   A3 = DV3 * DVP1 - DV1 * DVP3
A4 = DV1 * DVP2 - DV2 * DVP1   ERASE13 = (A2 2 + A3 2 + A4 2)1/2
Ai+3 = Ai/ERASE13
Ai = DVi-1/ERASE2   i = 1, 2, 3
"COMPUTE ECCENTRICITY, SEMI-MAJOR AXIS"
INCLINATION
ERASE14 = (1.0 - A7 * A7)1/2   ERASE15 = A7
OINCLI = AATAN (ERASE14, ERASE15)
CALL QUAD (ERASE15, ERASE14, OINCLI)
OINCLI = OINCLI/FLRAD
"RIGHT ASCENSION OF ASCENDING NODE"
ERASE16 = A5   ERASE17 = -A6
ASCNOD = AATAN (ERASE16, ERASE17)
CALL QUAD (ERASE17, ERASE16, ASCNOD)
ASCNOD = ASCNOD/FLRAD
"ARGUMENT OF PERIGE"
ERASE14 = A2 * ERASE17 + A3 * ERASE16
ERASE15 = A7 * (A3 * ERASE17 - A2 * ERASE16) + A4 * (A5 * ERASE16 - A6 * ERASE17)
ERASE18 = TAN-1 (ERASE15/ERASE14)
CALL QUAD (ERASE14, ERASE15, ERASE18)
ERASE16 = -ERASE10/ECCENT   ERASE17 = -ERASE9/ECCENT
ERASE19 = AATAN (ERASE16, ERASE17)
CALL QUAD (ERASE17, ERASE16, ERASE19)
PERIGE = ERASE18 + ERASE19   MERASE10 = PERIGE/2π
PERIGE = (PERIGE - 2π * FLOAT (MERASE10))/FLRAD
"MEAN ANOMALY"
ERASE14 = (-ERASE2 * ERASE16 / AXIMAJ * ERASE12)
ERASE15 = (ERASE17 + ECCENT / 1.0 + ECCENT * ERASE17)
ECANOM = AATAN (ERASE14, ERASE15)
CALL QUAD (ERASE15, ERASE14, ECANOM)
OMEANA = ECANOM - ECCENT * ERASE14
OMEANA < 0.0
<
≥
OMEANA = OMEAN + 2π
OMEANA = OMEANA/FLRAD
KEYTAP ≤ 0
≤
>
KTYPRT
-2
-3
LFO = 5
LFO = 7
400
LINOUT +LFO
>
≤ 58
LPAGE = LPAGE + 1
LINOUT = 3
WRITE PROPER HEADING
LOOKAN = 0
"BCD TAPE-EPHEMERIS OUTPUT"
KTYPRT = 5
≠
=
LOOKAN = 1   LINOUT = LINOUT + 4
WRITE (ON MBCD): DAYJL, KMOOUT KDAOUT, KYROUT, KHROUT, KMIOUT, SECOUT, TNORMO, IREV, DV(1-3), DVP(1-3), ALTIO, RADPRT, VTOTPR, GEOCEN, GEODET, OLAMO, MSTHR, MSTMIN, STSECO
KEYTAP = 0
<
>
=
KTYPRT
= 4,5
= 2,3
= 1
LINOUT = LINOUT + 1
WRITE (ON MBCD): AXIMAJ, ECCENT, OINCLI, ASCNOD, PERIGE, OMEANA
GO TO 660
KTYPRT ≤ 1
>
≤
KEYTAP < 0
<
≥
KTYPRT ≤ 2
>
≤
KEYTAP < 0
≥
<
KTYPRT ≤ 4
>
≤
KLAMRA = 1
GO TO 41
GO TO 3091
IJ = 1
NSTPRT = 0
=
≠
GO TO 61

FIG. 34.



61
NTPOLD = NTP
IJ = 1
NTP = 100
OLAMS = ERASE1
I = 0
65
I = I + 1
NS = 1
ERASE1 = SLON1
RALON = OLAMS - ERASD1
CALL HMATRX
MERASE > 0
KEYTAP ≥ 0
I < NSTPRT
GO TO 90
3091
IJ = IJ - 1
GO TO 3086
RTASC = OBSC2/FLRAD DECLIN = OBSC1/FLRAD
CALL RFCOR
ELEVAT = OBSM1/FLRAD AZIMUT = OBSM2/FLRAD
RANGES = OBSM3 RANRAT = OBSM4
AZRATE = OBSC6/FLRAD ELRATE = OBSC5/FLRAD
ERASE4 = CON1 * CON1 + CON2 * CON2
RARATE = (CON1 * CON7 - CON2 * CON6)/(ERASE4 * FLRAD)
DCRATE = {CON8 * ERASE4 - CON3 * (CON1 * CON6 + CON2 * CON7)} / {RTC2 * FLRAD * (ERASE4)^1/2}
COMPUTE: RIGHT ASCENSION RATE, DECLINATION RATE
KEYTAP ≤ 0
KTYPRT ≤ 2
LOOKAN = 1
LOOKAN = 1 LINOUT = LINOUT + 2
WRITE (ON MBCD): DAYJL, KMDOUT, KDAOUT, KYROUT, KHROUT, KMIOUT, SECOUT, TNORMD, IREV
STATION DATA - BCD TAPE - OUTPUT
LINOUT = LINOUT + 2
WRITE (ON MBCD): NUMSTA_NS, ELRATE, AZRATE, RARATE, DCRATE, ELEVAT, AZIMUT, RANGES, RANRAT, RTASC, DECLIN
KEYTAP < 0
GO TO 90
IJ ≤ 10
IJ = 10
NWORDS = 111
ITYPE ≤ 0
3078
NUMBER1 = ITYPE MERASE1 = NWORDS + 1
WRITE (ON MBIN): MERASE1, IJ, ANGDATj: j = 1,...., NWORDS
3075
ITYPE = -1
"WRITE EPHEMERIS ON BINARY TAPE"
MERASE1 = NWORDS + 31 NUMBER1 = ITYPE
WRITE (ON MBIN): MERASE1, DAYJL, KMDOUT, KDAOUT, KYROUT, KHROUT, KMIOUT, SECOUT, TNOROS, DV(1-3), DVP(1-3), ALTIO, RADPRT, VTOTPR, GEOCEN, GEODET, OLAMD, MSTHR, MSTMIN, STSECO, AXIMAJ, ECCENT, OINCLI, ASCNOD, PERIGE, OMEANA, IREV, IJ, (ANGDATj: j = 1,...., NWORDS)
IJ = 1
ITYPE ≤ 0
j = 11 * (IJ-1) + 1
NUMBERj + 1 = NUMSTA_NS ANGDATj + 2 = ELRATE
ANGDATj + 3 = AZRATE ANGDATj + 4 = RARATE
ANGDATj + 5 = DCRATE ANGDATj + 6 = ELEVAT
ANGDATj + 7 = AZIMUT ANGDATj + 8 = RANGES
ANGDATj + 9 = RANRAT ANGDATj + 10 = RTASC
ANGDATj + 11 = DECLIN
I < NSTPRT
IJ = IJ + 1
90
3086
NWORDS = IJ * 11 + 1
GO TO 3075
ITYPE ≤ 0
ITYPE = 1
GO TO 3078
GO TO 65
I < NSTPRT
IREC = IREC - 1
II < LUP
660
NTP = NTPOLD
GO TO 606
ISAVE ≤ 0
LUP = ISAVE
IREC = 1
GO TO 605
II = II + 1
GO TO 610
685
REWIND MMTAPE
GO TO 1000

FIG. 35.

SUBROUTINE RFCOR

THIS SUBROUTINE COMPUTES THE REFRACTION CORRECTIONS.(SEE SECTION IV D.REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
ERASE(1-20)			INTERMEDIATE VARIABLES
TEMPE			INTERMEDIATE VARIABLE

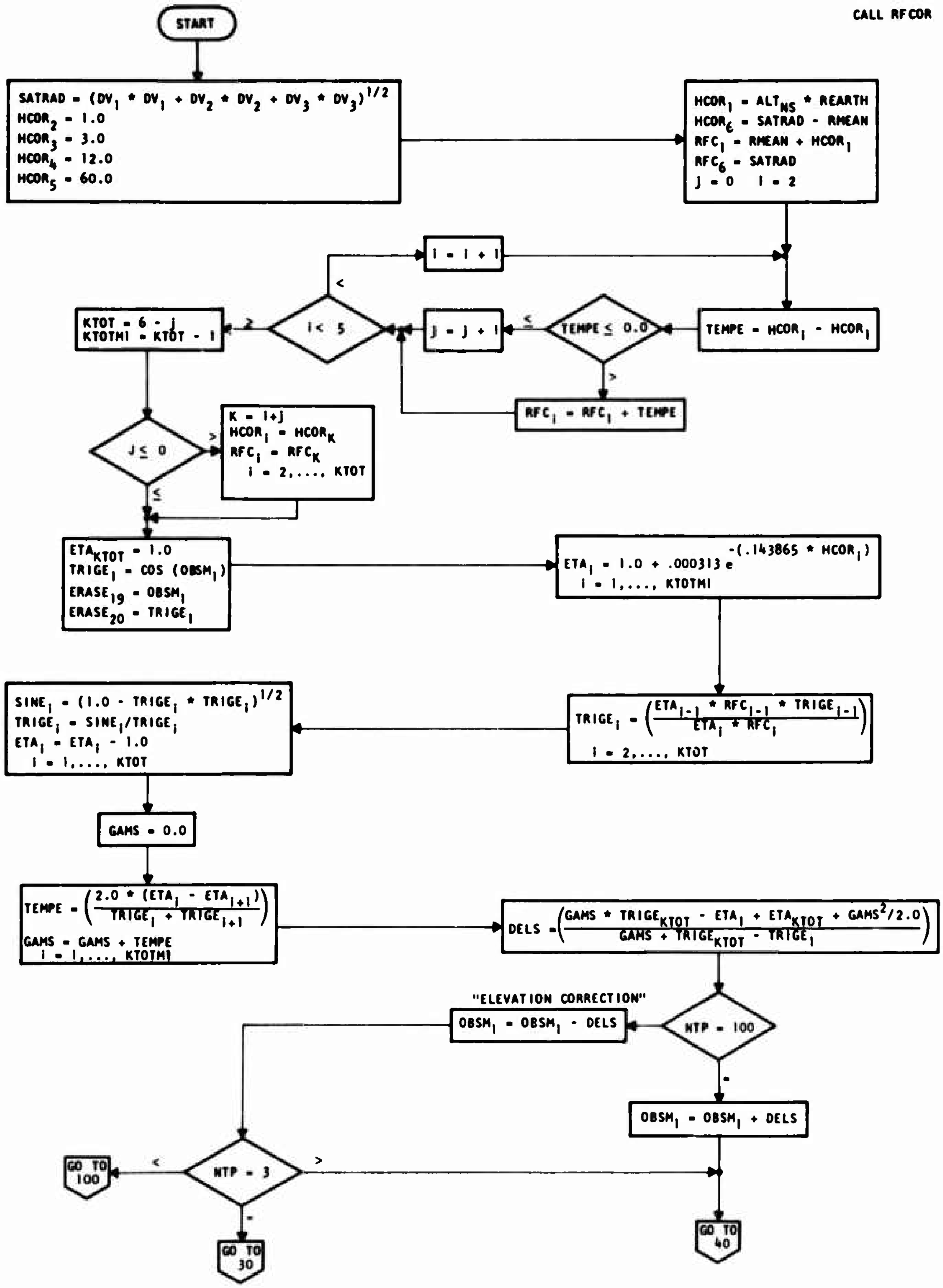

START
SATRAD = (DV1 * DV1 + DV2 * DV2 + DV3 * DV3)^1/2
HCOR2 = 1.0
HCOR3 = 3.0
HCOR4 = 12.0
HCOR5 = 60.0
HCOR1 = ALTNS * REARTH
HCOR6 = SATRAD - RMEAN
RFC1 = RMEAN + HCOR1
RFC6 = SATRAD
J = 0 I = 2
I = I + 1
TEMPE = HCORI - HCOR1
TEMPE ≤ 0.0
J = J + 1
RFCI = RFCI + TEMPE
I < 5
KTOT = 6 - J
KTOTMI = KTOT - 1
J ≤ 0
K = I+J
HCORI = HCORK
RFCI = RFCK
I = 2,...., KTOT
ETAKTOT = 1.0
TRIGE1 = COS (OBSM1)
ERASE19 = OBSM1
ERASE20 = TRIGE1
ETAI = 1.0 + .000313 e^-(.143865 * HCORI)
I = 1,...., KTOTMI
TRIGEI = (ETAI-1 * RFCI-1 * TRIGEI-1 / ETAI * RFCI)
I = 2,...., KTOT
SINEI = (1.0 - TRIGEI * TRIGEI)^1/2
TRIGEI = SINEI/TRIGEI
ETAI = ETAI - 1.0
I = 1,...., KTOT
GAMS = 0.0
TEMPE = (2.0 * (ETAI - ETAI+1) / TRIGEI + TRIGEI+1)
GAMS = GAMS + TEMPE
I = 1,...., KTOTMI
DELS = (GAMS * TRIGEKTOT - ETA1 + ETAKTOT + GAMS²/2.0 / GAMS + TRIGEKTOT - TRIGE1)
"ELEVATION CORRECTION"
OBSM1 = OBSM1 - DELS
NTP - 100
OBSM1 = OBSM1 + DELS
NTP - 3
GO TO 100
GO TO 30
GO TO 40

FIG. 36.

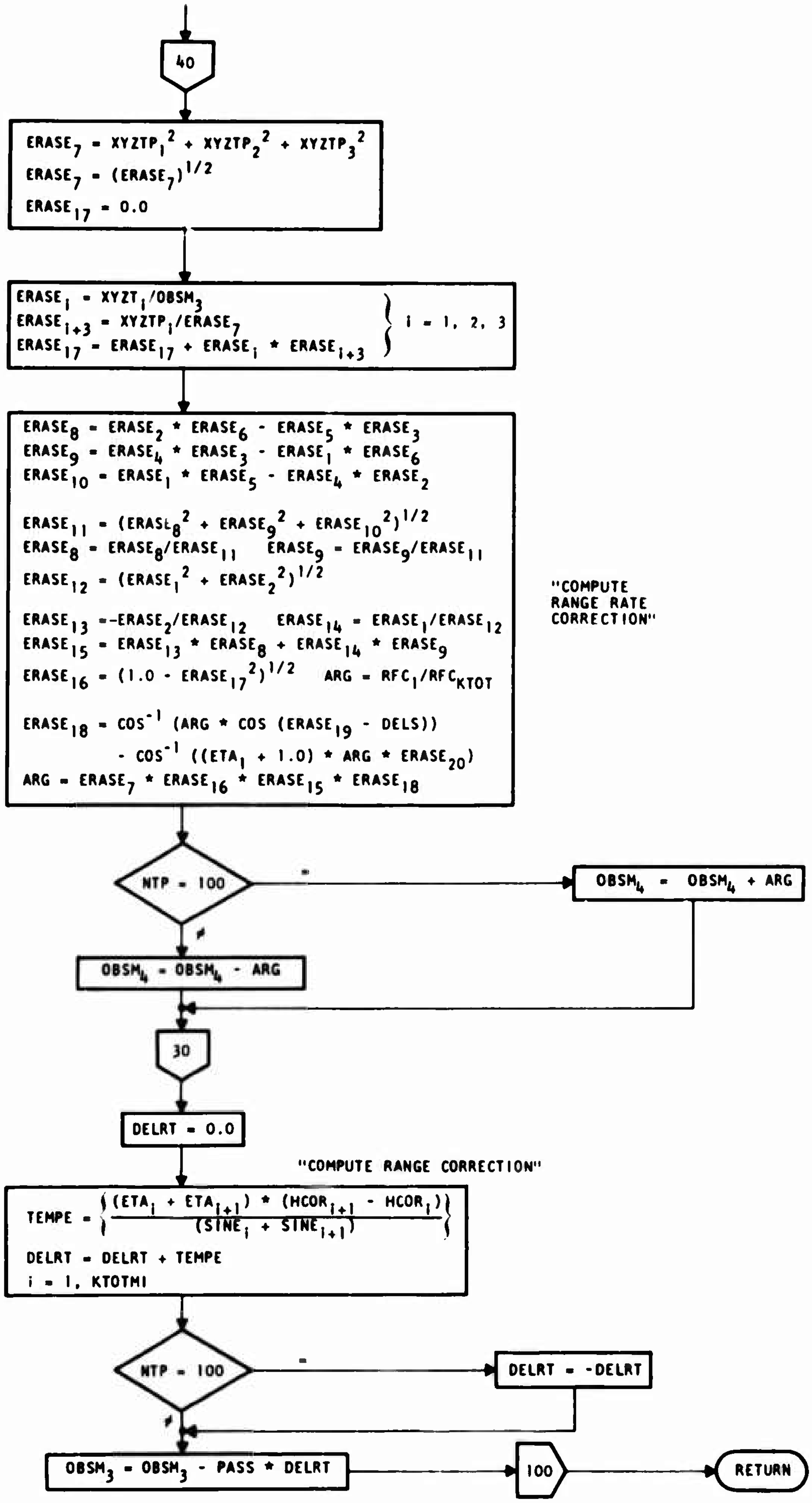

40
$ERASE_7 = XYZTP_1^2 + XYZTP_2^2 + XYZTP_3^2$
$ERASE_7 = (ERASE_7)^{1/2}$
$ERASE_{17} = 0.0$
$ERASE_i = XYZT_i/OBSM_3$
$ERASE_{i+3} = XYZTP_i/ERASE_7$
$ERASE_{17} = ERASE_{17} + ERASE_i * ERASE_{i+3}$
i = 1, 2, 3
$ERASE_8 = ERASE_2 * ERASE_6 - ERASE_5 * ERASE_3$
$ERASE_9 = ERASE_4 * ERASE_3 - ERASE_1 * ERASE_6$
$ERASE_{10} = ERASE_1 * ERASE_5 - ERASE_4 * ERASE_2$
$ERASE_{11} = (ERASE_8^2 + ERASE_9^2 + ERASE_{10}^2)^{1/2}$
$ERASE_8 = ERASE_8/ERASE_{11}$ $ERASE_9 = ERASE_9/ERASE_{11}$
$ERASE_{12} = (ERASE_1^2 + ERASE_2^2)^{1/2}$
$ERASE_{13} = -ERASE_2/ERASE_{12}$ $ERASE_{14} = ERASE_1/ERASE_{12}$
$ERASE_{15} = ERASE_{13} * ERASE_8 + ERASE_{14} * ERASE_9$
$ERASE_{16} = (1.0 - ERASE_{17}^2)^{1/2}$ $ARG = RFC_1/RFC_{KTOT}$
$ERASE_{18} = \cos^{-1} (ARG * \cos (ERASE_{19} - DELS))$
$- \cos^{-1} ((ETA_1 + 1.0) * ARG * ERASE_{20})$
$ARG = ERASE_7 * ERASE_{16} * ERASE_{15} * ERASE_{18}$
"COMPUTE RANGE RATE CORRECTION"
NTP = 100
=
≠
$OBSM_4 = OBSM_4 + ARG$
$OBSM_4 = OBSM_4 - ARG$
30
DELRT = 0.0
"COMPUTE RANGE CORRECTION"
$TEMPE = \left\{\frac{(ETA_i + ETA_{i+1}) * (HCOR_{i+1} - HCOR_i)}{(SINE_i + SINE_{i+1})}\right\}$
DELRT = DELRT + TEMPE
i = 1, KTOTMI
NTP = 100
=
≠
DELRT = -DELRT
$OBSM_3 = OBSM_3 - PASS * DELRT$
100
RETURN

FIG. 37.

SUBROUTINE SETCON

THIS SUBROUTINE COMPUTES PROGRAM CONSTANTS AND CERTAIN INITIALIZATION FROM THE INPUT DATA.

VARIABLE	EQUA	REF	DEFINITION
MERASE(1)			SEE INPUT LISTING
ERASE(1-5)	5-7	1	INTERMEDIATE VARIABLES

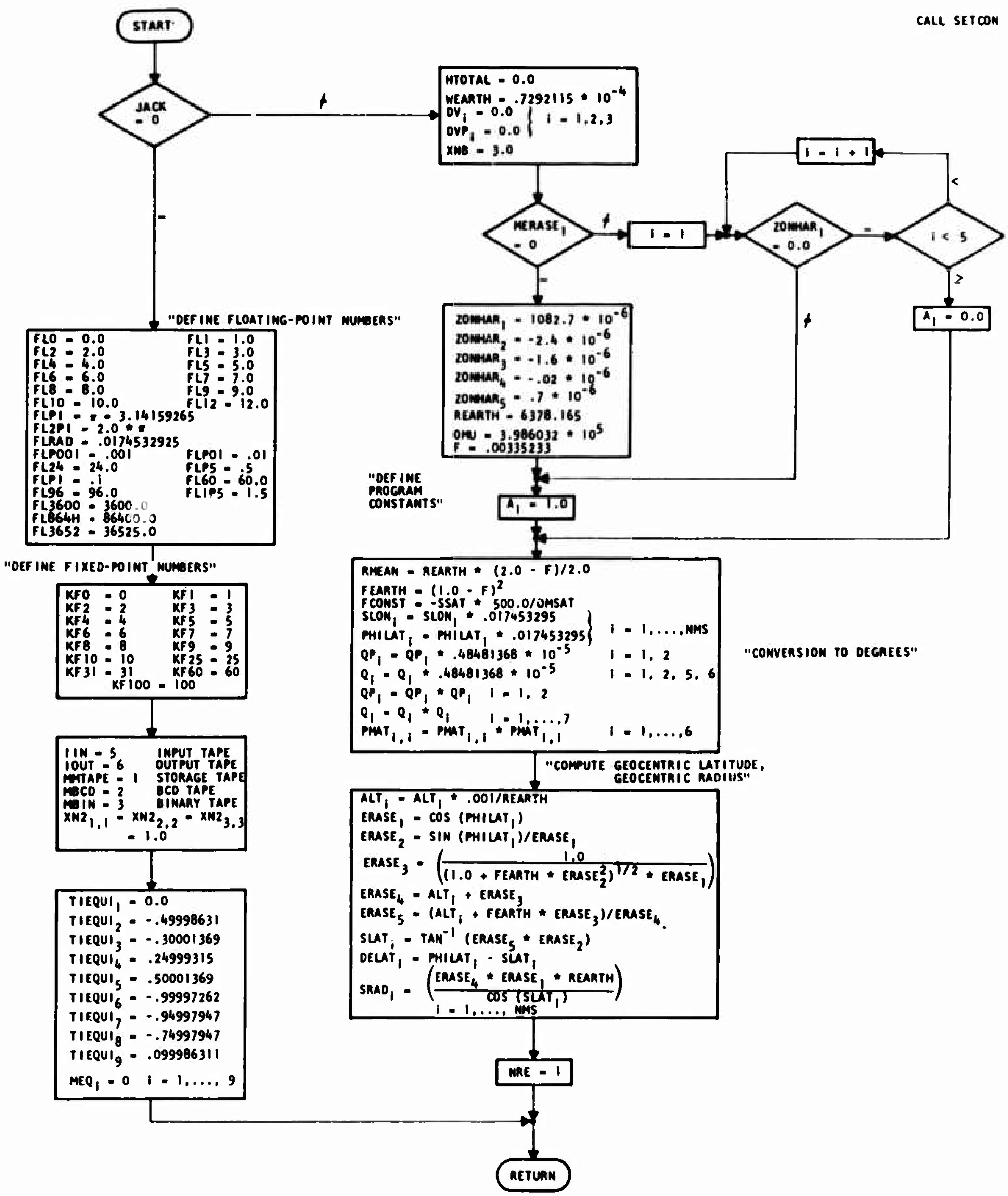

START
JACK = 0
HTOTAL = 0.0
WEARTH = .7292115 * 10^-4
DV_i = 0.0
DVP_i = 0.0
i = 1,2,3
XNB = 3.0
HERASE_i = 0
i = 1
ZONHAR_i = 0.0
i < 5
i = i + 1
A_i = 0.0
ZONHAR_1 = 1082.7 * 10^-6
ZONHAR_2 = -2.4 * 10^-6
ZONHAR_3 = -1.6 * 10^-6
ZONHAR_4 = -.02 * 10^-6
ZONHAR_5 = .7 * 10^-6
REARTH = 6378.165
OMU = 3.986032 * 10^5
F = .00335233
"DEFINE PROGRAM CONSTANTS"
A_i = 1.0
"DEFINE FLOATING-POINT NUMBERS"
FL0 = 0.0 FL1 = 1.0
FL2 = 2.0 FL3 = 3.0
FL4 = 4.0 FL5 = 5.0
FL6 = 6.0 FL7 = 7.0
FL8 = 8.0 FL9 = 9.0
FL10 = 10.0 FL12 = 12.0
FLPI = π = 3.14159265
FL2PI = 2.0 * π
FLRAD = .0174532925
FLP001 = .001 FLP01 = .01
FL24 = 24.0 FLP5 = .5
FLP1 = .1 FL60 = 60.0
FL96 = 96.0 FL1P5 = 1.5
FL3600 = 3600.0
FL864H = 86400.0
FL3652 = 36525.0
"DEFINE FIXED-POINT NUMBERS"
KF0 = 0 KF1 = 1
KF2 = 2 KF3 = 3
KF4 = 4 KF5 = 5
KF6 = 6 KF7 = 7
KF8 = 8 KF9 = 9
KF10 = 10 KF25 = 25
KF31 = 31 KF60 = 60
KF100 = 100
IIN = 5 INPUT TAPE
IOUT = 6 OUTPUT TAPE
MMTAPE = 1 STORAGE TAPE
MBCD = 2 BCD TAPE
MBIN = 3 BINARY TAPE
XN2_1,1 = XN2_2,2 = XN2_3,3 = 1.0
TIEQUI_1 = 0.0
TIEQUI_2 = -.49998631
TIEQUI_3 = -.30001369
TIEQUI_4 = .24999315
TIEQUI_5 = .50001369
TIEQUI_6 = -.99997262
TIEQUI_7 = -.94997947
TIEQUI_8 = -.74997947
TIEQUI_9 = .099986311
MEQ_i = 0 i = 1,...., 9
RMEAN = REARTH * (2.0 - F)/2.0
FEARTH = (1.0 - F)^2
FCONST = -SSAT * 500.0/OMSAT
SLON_i = SLON_i * .017453295
PHILAT_i = PHILAT_i * .017453295
i = 1,....,NMS
QP_i = QP_i * .48481368 * 10^-5 i = 1, 2
Q_i = Q_i * .48481368 * 10^-5 i = 1, 2, 5, 6
QP_i = QP_i * QP_i i = 1, 2
Q_i = Q_i * Q_i i = 1,....,7
PMAT_i,i = PMAT_i,i * PMAT_i,i i = 1,....,6
"CONVERSION TO DEGREES"
"COMPUTE GEOCENTRIC LATITUDE, GEOCENTRIC RADIUS"
ALT_i = ALT_i * .001/REARTH
ERASE_1 = COS (PHILAT_i)
ERASE_2 = SIN (PHILAT_i)/ERASE_1
ERASE_3 = (1.0 / ((1.0 + FEARTH * ERASE_2^2)^1/2 * ERASE_1))
ERASE_4 = ALT_i + ERASE_3
ERASE_5 = (ALT_i + FEARTH * ERASE_3)/ERASE_4
SLAT_i = TAN^-1 (ERASE_5 * ERASE_2)
DELAT_i = PHILAT_i - SLAT_i
SRAD_i = (ERASE_4 * ERASE_1 * REARTH / COS (SLAT_i))
i = 1,...., NMS
NRE = 1
RETURN
CALL SETCON

FIG. 38.

SUBROUTINE TRAMAT

THIS SUBROUTINE COMPUTES THE STATE TRANSITION MATRIX (SECTION VI B,REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
PHITR(6,6)			INTERMEDIATE MATRIX
TEMP			INTERMEDIATE VARIABLE
TEMPE	96	1	INTERMEDIATE VARIABLE

CALL TRAMAT

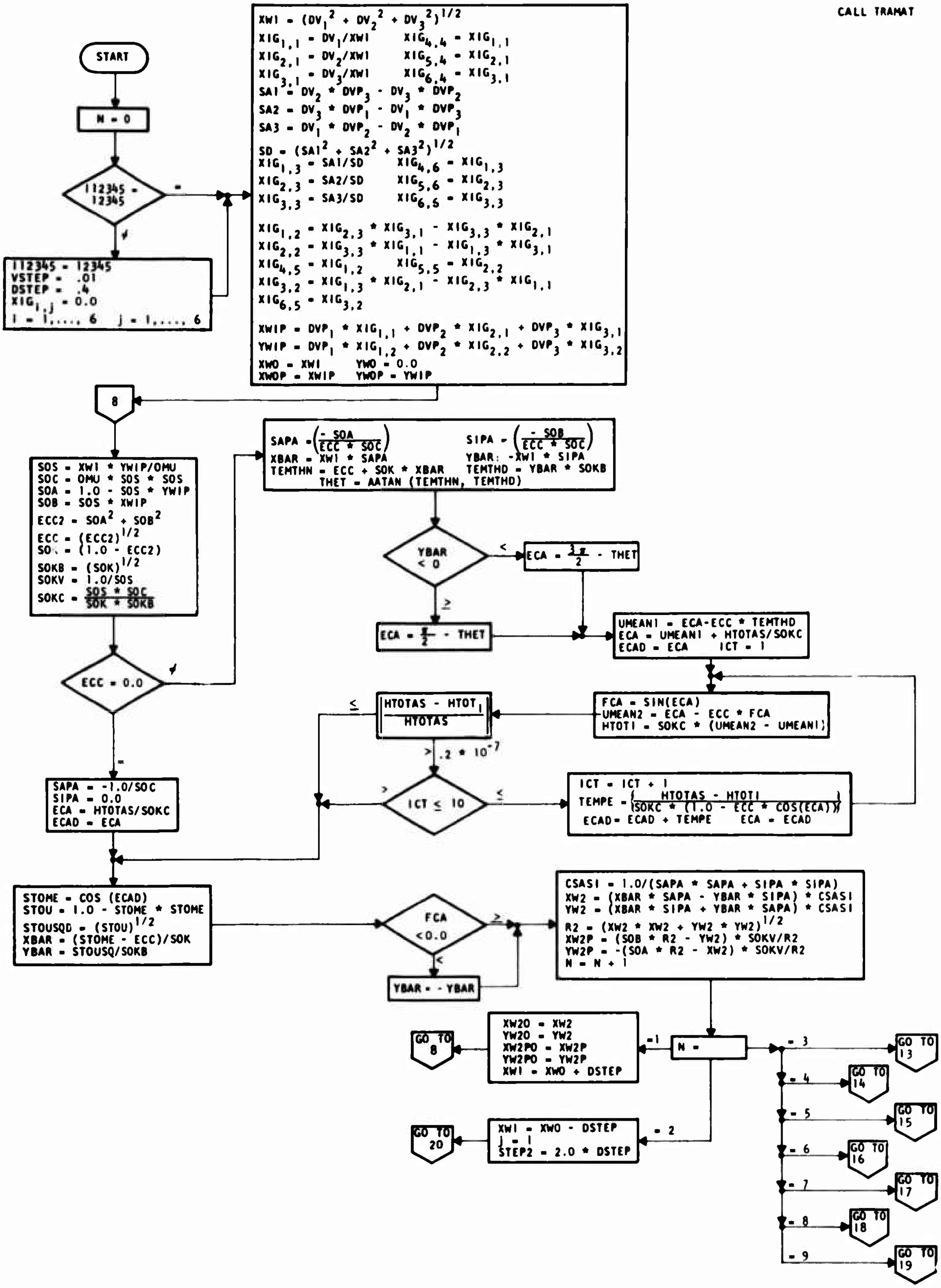


FIG. 39.

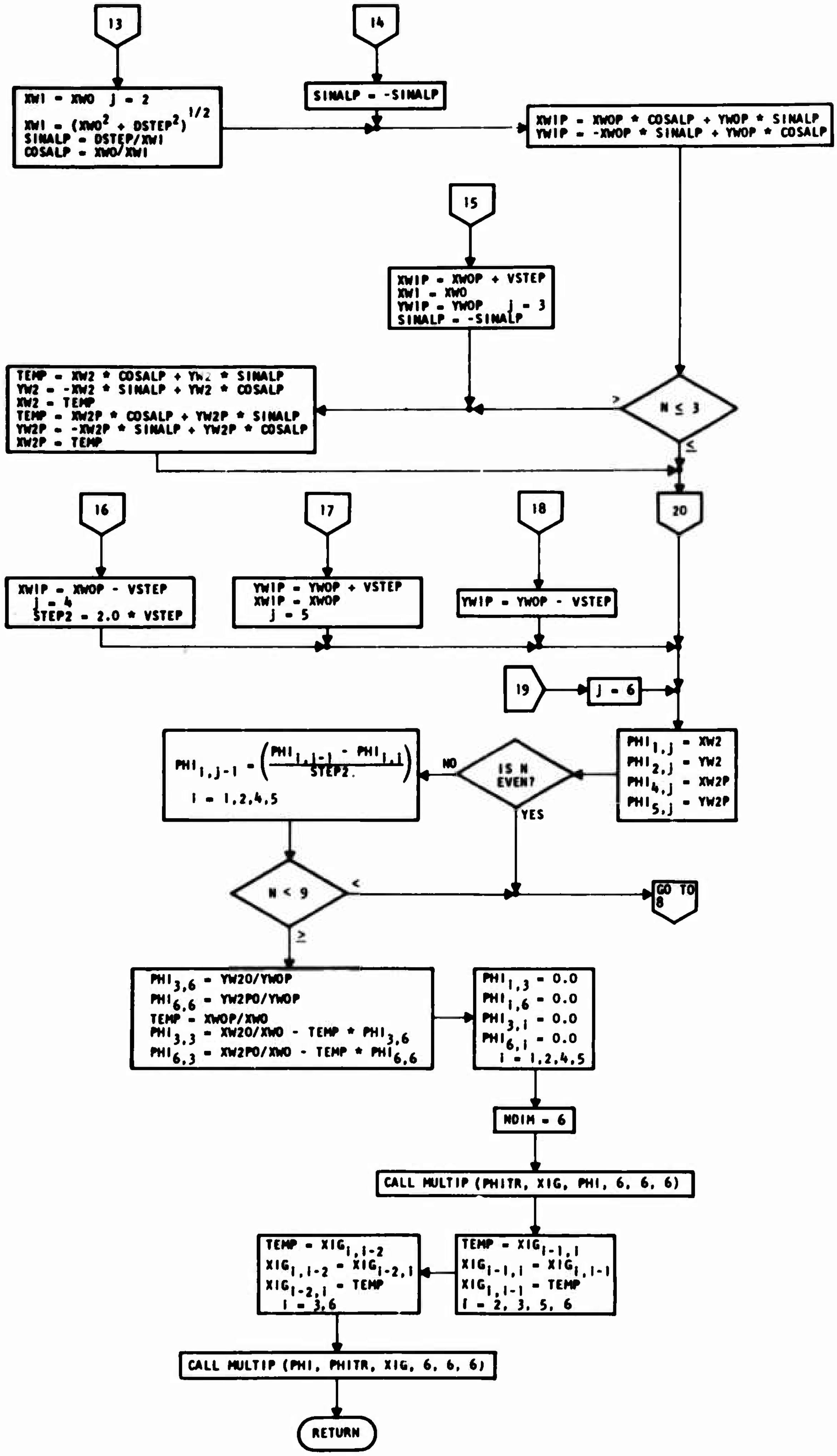

13
14
XWI = XWO J = 2
XWI = (XWO² + DSTEP²)^1/2
SINALP = DSTEP/XWI
COSALP = XWO/XWI
SINALP = -SINALP
XWIP = XWOP * COSALP + YWOP * SINALP
YWIP = -XWOP * SINALP + YWOP * COSALP
15
XWIP = XWOP + VSTEP
XWI = XWO
YWIP = YWOP J = 3
SINALP = -SINALP
TEMP = XW2 * COSALP + YW2 * SINALP
YW2 = -XW2 * SINALP + YW2 * COSALP
XW2 = TEMP
TEMP = XW2P * COSALP + YW2P * SINALP
YW2P = -XW2P * SINALP + YW2P * COSALP
XW2P = TEMP
N ≤ 3
16
17
18
20
XWIP = XWOP - VSTEP
J = 4
STEP2 = 2.0 * VSTEP
YWIP = YWOP + VSTEP
XWIP = XWOP
J = 5
YWIP = YWOP - VSTEP
19
J = 6
PHI1,J-1 = ((PHI1,J-1 - PHI1,J) / STEP2)
I = 1,2,4,5
NO
IS N EVEN?
YES
PHI1,J = XW2
PHI2,J = YW2
PHI4,J = XW2P
PHI5,J = YW2P
N < 9
GO TO 8
PHI3,6 = YW20/YWOP
PHI6,6 = YW2PO/YWOP
TEMP = XWOP/XWO
PHI3,3 = XW20/XWO - TEMP * PHI3,6
PHI6,3 = XW2PO/XWO - TEMP * PHI6,6
PHI1,3 = 0.0
PHI1,6 = 0.0
PHI3,I = 0.0
PHI6,I = 0.0
I = 1,2,4,5
NDIM = 6
CALL MULTIP (PHITR, XIG, PHI, 6, 6, 6)
TEMP = XIGI,I-2
XIGI,I-2 = XIGI-2,I
XIGI-2,I = TEMP
I = 3,6
TEMP = XIGI-1,I
XIGI-1,I = XIGI,I-1
XIGI,I-1 = TEMP
I = 2, 3, 5, 6
CALL MULTIP (PHI, PHITR, XIG, 6, 6, 6)
RETURN

FIG. 40.

SUBROUTINE TRANSF

THE MAIN FUNCTION OF THIS SUBROUTINE IS TO COMPUTE THE ELEVATION, AZIMUTH, RANGE, RANGE RATE, ELEVATION RATE, AZIMUTH RATE AND RANGE ACCELERATION. (SECTION VII B, REFERENCE 1)

VARIABLE	EQUA	REF	DEFINITION
CON(1-3)	16	1	INTERMEDIATE VARIABLES
CON(8)	17	1	INTERMEDIATE VARIABLE, $\dot{Z}$
MERASE(1)			=1, STATION CAN SEE THE SATELLITE =-1, STATION CAN NOT SEE THE SATELLITE
XM(3,3)	16, 17	1	INTERMEDIATE VARIABLES

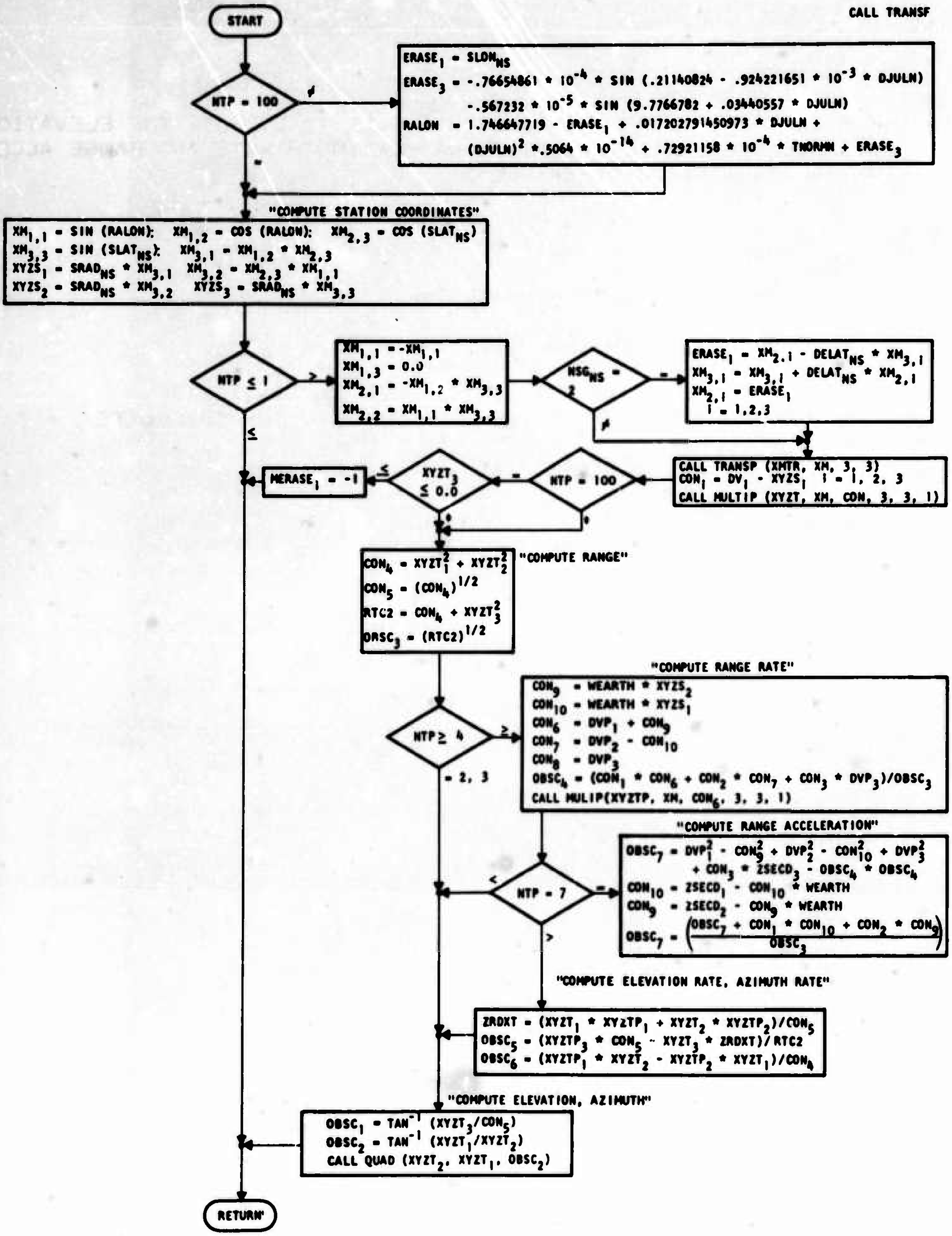

START
CALL TRANSF
NTP = 100
≠
=
ERASE1 = SLONNS
ERASE3 = -.76654861 * 10^-4 * SIN (.21140824 - .924221651 * 10^-3 * DJULN)
-.567232 * 10^-5 * SIN (9.7766782 + .03440557 * DJULN)
RALON = 1.746647719 - ERASE1 + .017202791450973 * DJULN +
(DJULN)^2 *.5064 * 10^-14 + .72921158 * 10^-4 * THORMN + ERASE3
"COMPUTE STATION COORDINATES"
XM1,1 = SIN (RALON); XM1,2 = COS (RALON); XM2,3 = COS (SLATNS)
XM3,3 = SIN (SLATNS); XM3,1 = XM1,2 * XM2,3
XYZS1 = SRADNS * XM3,1 XM3,2 = XM2,3 * XM1,1
XYZS2 = SRADNS * XM3,2 XYZS3 = SRADNS * XM3,3
NTP ≤ 1
>
≤
XM1,1 = -XM1,1
XM1,3 = 0.0
XM2,1 = -XM1,2 * XM3,3
XM2,2 = XM1,1 * XM3,3
NSGNS = 2
=
≠
ERASE1 = XM2,1 - DELATNS * XM3,1
XM3,1 = XM3,1 + DELATNS * XM2,1
XM2,1 = ERASE1
1 = 1,2,3
CALL TRANSP (XMTR, XM, 3, 3)
CON1 = DV1 - XYZS1 1 = 1, 2, 3
CALL MULTIP (XYZT, XM, CON, 3, 3, 1)
NTP = 100
=
≠
XYZT3 ≤ 0.0
≤
MERASE1 = -1
"COMPUTE RANGE"
CON4 = XYZT1^2 + XYZT2^2
CON5 = (CON4)^1/2
RTC2 = CON4 + XYZT3^2
OBSC3 = (RTC2)^1/2
"COMPUTE RANGE RATE"
NTP ≥ 4
>
= 2, 3
CON9 = WEARTH * XYZS2
CON10 = WEARTH * XYZS1
CON6 = DVP1 + CON9
CON7 = DVP2 - CON10
CON8 = DVP3
OBSC4 = (CON1 * CON6 + CON2 * CON7 + CON3 * DVP3)/OBSC3
CALL MULIP(XYZTP, XM, CON6, 3, 3, 1)
"COMPUTE RANGE ACCELERATION"
NTP = 7
<
=
>
OBSC7 = DVP1^2 - CON9^2 + DVP2^2 - CON10^2 + DVP3^2
+ CON3 * ZSECD3 - OBSC4 * OBSC4
CON10 = ZSECD1 - CON10 * WEARTH
CON9 = ZSECD2 - CON9 * WEARTH
OBSC7 = ((OBSC7 + CON1 * CON10 + CON2 * CON9) / OBSC3)
"COMPUTE ELEVATION RATE, AZIMUTH RATE"
ZRDXT = (XYZT1 * XYZTP1 + XYZT2 * XYZTP2)/CON5
OBSC5 = (XYZTP3 * CON5 - XYZT3 * ZRDXT)/RTC2
OBSC6 = (XYZTP1 * XYZT2 - XYZTP2 * XYZT1)/CON4
"COMPUTE ELEVATION, AZIMUTH"
OBSC1 = TAN^-1 (XYZT3/CON5)
OBSC2 = TAN^-1 (XYZT1/XYZT2)
CALL QUAD (XYZT2, XYZT1, OBSC2)
RETURN

FIG. 41.

SUBROUTINE ADDITI OR SUBROUTINE SUBTRA

THIS SUBROUTINE ADDS OR SUBTRACTS 2 MATRICES.

SUBROUTINE MULTIP

THIS SUBROUTINE MULTIPIES 2 MATRICES.(NOTE,IT IS ASSUMED THAT THE FORTRAN DIMENSION OF EACH MATRIX IS EQUAL)

SUBROUTINE TRANSP

THIS SUBROUTINE OBTAINS THE TRANSPOSE OF A MATRIX.

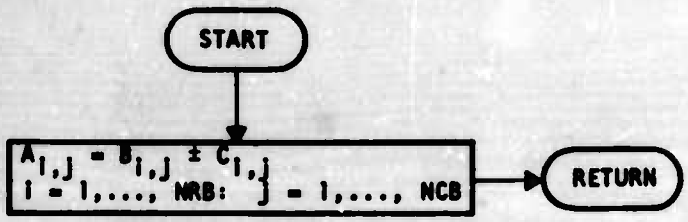
SUBROUTINE AATAN

THIS SUBROUTINE COMPUTES THE ARCTANGENT.(GIVEN THE SINE AND COSINE)

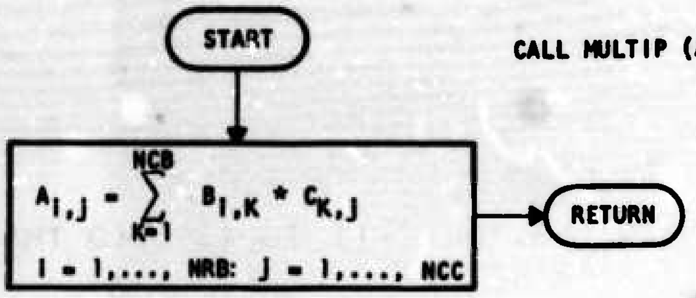
SUBROUTINE QUAD

THIS SUBROUTINE OBTAINS THE PROPER QUADRANT OF AN ANGLE AFTER IT HAS BEEN OBTAINED BY THE ARCTANGENT SUBROUTINE.

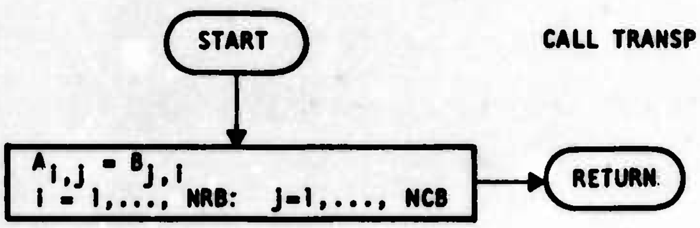
CALL ADDITI (A,B,C,NRB,NCB) OR
CALL SUBTRA (A,B,C,NRB,NCB)



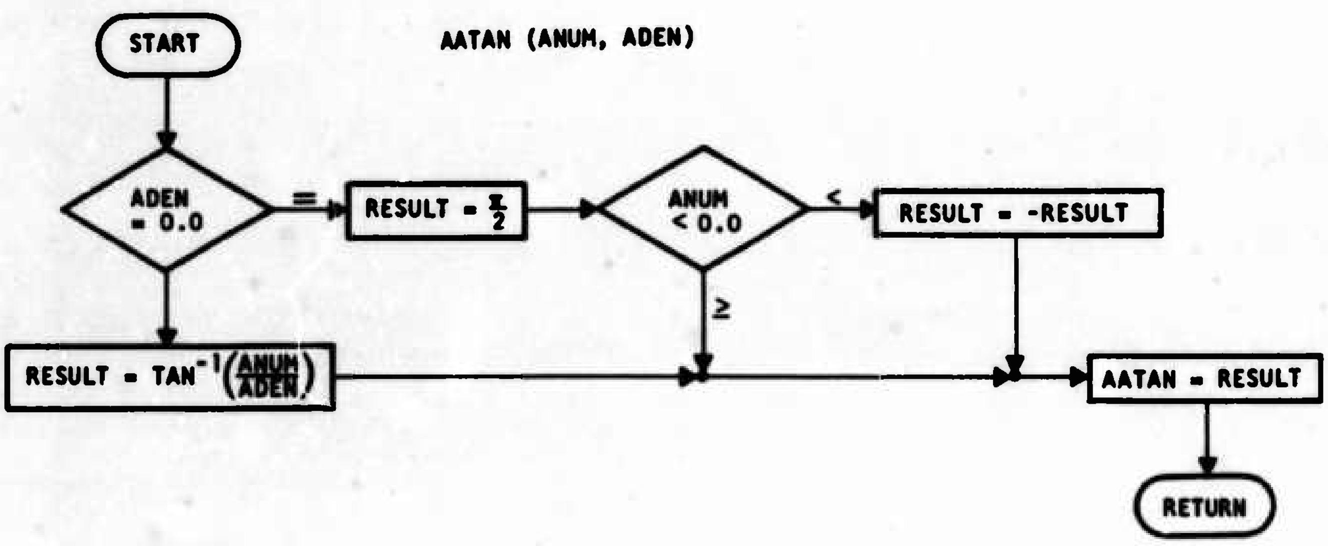
CALL MULTIP (A,B,C,NRB,NCB,NCC)



CALL TRANSP (A,B,NRB,NCB)



AATAN (ANUM, ADEN)



CALL QUAD (X,Y,ALPHA)

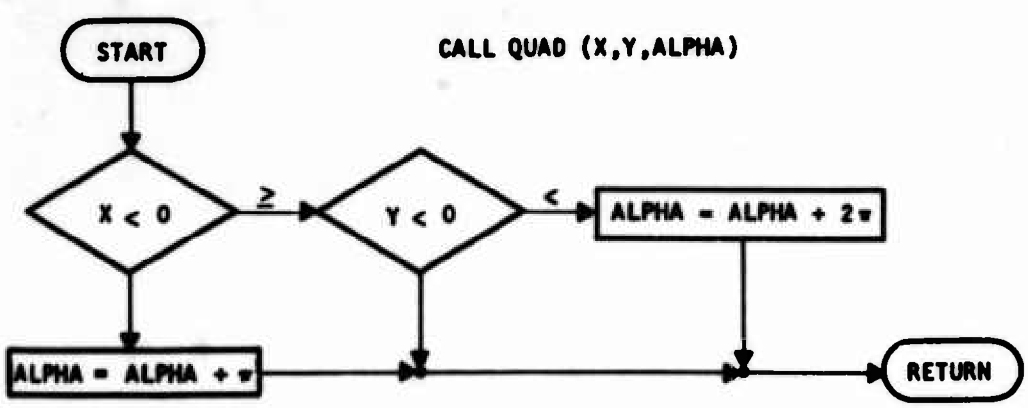


FIG. 42.

SUBROUTINE BCDFL OR SUBROUTINE BCDFX

SUBROUTINE BCDFL CONVERTS A BCD WORD TO A REAL(FLOATING POINT) NUMBER. SUBROUTINE BCDFX CONVERTS A BCD WORD TO AN INTEGER(FIXED POINT) NUMBER. THE FORTRAN CALLING SEQUENCE IS

```
CALL BCDFL(ARG1,N,ARG2,J)
          OR
CALL BCDFX(ARG1,N,ARG2,J)
```

```
ARG1- WORD TO BE CONVERTED
   N- NUMBER OF CHARACTER OF ARG1 TO BE CONSIDERED IN THE
      CONVERSION
ARG2- THE CONVERTED NUMBER (REAL OR INTEGER),ALWAYS POSITIVE.
   J- =-1,ERROR WORD CAN NOT BE CONVERTED
      =0, WORD HAS BEEN CONVERTED
```

NOTE. THE WORD MUST CONSISTS OF NUMERICAL BCD CHARACTERS.THERE IS NO FLOWCHART AND VARIABLES OF THE SUBROUTINE HAVE NOT BEEN DEFINED.

SUBROUTINE BCDSTO

THIS SUBROUTINE IS USED TO STORE BCD INFORMATION.THERE IS NO FLOWCHART.

SUBROUTINE SYMMET

THIS SUBROUTINE SYMMETRIZES THE COVARIANCE MATRIX (EQUATION 51, REFERENCE 1) AND THE MATRIX K*H*P (EQUATION 52 REFERENCE 1.) THERE IS NO FLOWCHART.

SUBROUTINE OVPUN AND SUBROUTINE NOVPU

SUBROUTINE OVPUN CONVERTS A BCD CHARACTER TO A REAL(FLOATING POINT) NUMBER. SUBROUTINE NOVPU CONVERTS A BCD CHARACTER TO AN INTEGER(FIXED POINT) NUMBER. THE FORTRAN CALLING SEQUENCE IS

```
CALL OVPUN(ARG1,ARG2,J)
          OR
CALL NOVPU(ARG1,ARG2,J)
```

ARG1- CHARACTER TO BE INVERTED
ARG2- THE CONVERTED NUMBER (REAL OR INTEGER)
J- =-1,ERROR.CHARACTER CAN NOT BE CONVERTED
=0, ARG2 IS POSITIVE
=1, ARG2 IS NEGATIVE

THE NET RESULT OF THESE SUBROUTINES IS TO CONVERT AN OVERPUNCH(ON OBSERVATION CARD) TO A NUMBER.THERE IS NO FLOWCHART AND VARIABLES OF THE SUBROUTINES HAVE NOT BEEN DEFINED.

VII. REFERENCES

1. Minka, K. "Orbit Determination and Analysis by the Minimum Variance Method." Martin Company, Baltimore Division, ER 13950. Prepared for AFCRL, OAR (CRMXA), USAF. AFCRL 65-579, August 1965.

2. Jacchia, L. G. "The Temperature Above the Thermopause." Smithsonian Institution Astrophysical Observatory, Special Report No. 150. Cambridge, Massachusetts, 1964.

3. Minka, K., Clemenz, B. E. and Fein, J. "Geophysical Constant and Observation Bias Estimation from Satellite Observations." Digital Computer Programs. Martin Company, Baltimore Division. To be published.

APPENDIX

A. TIMING ERROR

A timing error introduces errors in satellite observation, which, obviously, will appear along the direction of the satellite velocity vector. Thus, they are distinctly different from normal observation errors.

If at the time of an observation, the components of the satellite velocity vector are $\dot{x}$, $\dot{y}$, $\dot{z}$ and the components of the acceleration vector are $\ddot{x}$, $\ddot{y}$, $\ddot{z}$, the error in position due to a standard timing error σ will be,

$$\Delta x_t = |\dot{x}\sigma| \qquad \text{(A. 1a)}$$

$$\Delta y_t = |\dot{y}\sigma| \qquad \text{(A. 1b)}$$

$$\Delta z_t = |\dot{z}\sigma| \qquad \text{(A. 1c)}$$

and the error in velocity will be

$$\Delta \dot{x}_t = |\ddot{x}\sigma| \qquad \text{(A. 2a)}$$

$$\Delta \dot{y}_t = |\ddot{y}\sigma| \qquad \text{(A. 2b)}$$

$$\Delta \dot{z}_t = |\ddot{z}\sigma| \qquad \text{(A. 2c)}$$

which will give a covariance matrix of the position and velocity vector due to the timing error:

$$P_t = \begin{bmatrix} \Delta x_t^2 & 0 \ldots & & & & 0 \\ 0 & \Delta y_t^2 & & & & \vdots \\ \vdots & & \Delta z_t^2 & & & \\ & & & \Delta \dot{x}_t^2 & & \vdots \\ \vdots & & & & \Delta \dot{y}_t^2 & 0 \\ 0 \ldots & & & \ldots 0 & & \Delta \dot{z}_t^2 \end{bmatrix} \qquad \text{(A. 3)}$$

Thus, the total covariance matrix at an observation time including the timing error will be (see Ref. 1, Section V-D)

$$R = H(t_{k+1})\,\Phi(t_{k+1}, t_k)\,P'(t_k)\,\Phi^T(t_{k+1}, t_k)\,H^T(t_{k+1})$$

$$+ H(t_{k+1})\,P_t(t_{k+1})\,H^T(t_{k+1}) + Q(t_{k+1}) \tag{A.4}$$

which can be rearranged

$$R = H(t_{k+1})\Big[\Phi(t_{k+1}, t_k)\,P'(t_k)\,\Phi^T(t_{k+1}, t_k)$$

$$+ P_t(t_{k+1})\Big]\,H^T(t_{k+1}) + Q(t_{k+1}) \tag{A.5}$$

This covariance matrix is expressed in terms of observations and replaces the matrix inside the square brackets in Eq 50, Ref. 1.

It must be pointed out that the timing error σ can be either for an individual observation or a particular station or the whole system. In a general case, when the timing error for a particular station will not be known, the system standard timing error can be used which, generally, will be more easily estimated. The present program utilizes a system timing error which is an input value.

B. SMOOTHING EQUATIONS

Smoothing can be considered a special case of filtering in the sense that the observations are replaced by the state variables which in our case are the six orbital elements in the form of position and velocity vectors. Returning to Eqs (49), (50), (51) and (52) of Ref. 1:

$$\hat{x}(t_{k+1}) = K(t_{k+1})\left[y'(t_{k+1}) - \hat{y}'(t_{k+1})\right] \tag{A.6}$$

$$K(t_{k+1}) = P(t_{k+1})\,H^T(t_{k+1})\Big[H(t_{k+1})\,P(t_{k+1})\,H^T(t_{k+1})$$

$$+ Q(t_{k+1})\Big]^{-1} \tag{A.7}$$

$$P(t_{k+1}) = \Phi(t_{k+1}, t_k)\,P'(t_{k+1})\,\Phi^T(t_{k+1}, t_k) \tag{A.8}$$

$$P'(t_{k+1}) = P(t_{k+1}) - K(t_{k+1})\,H(t_{k+1})\,P(t_{k+1}) \tag{A.9}$$

We can consider that instead of a series of observations obtained at discrete times, we have a series of estimates of the state variables and their covariance matrices. These estimates of the state variables and the corresponding covariance matrices are obtained in the process of regular filtering and stored in the computer.

Assuming that at time t_n we have an estimate $\hat{x}(t_n | t_n)$ based on observations obtained up to and including time t_n, we can update a previous estimate at time t_k, $\hat{x}(t_k | t_k)$ based on data which includes time t_n, $(t_k < t_n)$. The updated estimate will be designated $\hat{x}(t_k | t_n)$. The process will now consist of computing the weighting matrices from the covariance matrices of two sets of estimates at each data point, and correcting one set of the estimates.

Returning to Eqs (A.6), (A.7), (A.8) and (A.9) we can make the following deductions. Since the observations are now replaced by estimates of the state variables or the position and velocity vector, the matrix H and its transpose will be a unit matrix because the components of the position and velocity vector are independent variables. The Q matrix will now be the covariance matrix $P(t_k | t_k)$ of the estimate $\hat{x}(t_k | t_k)$. Then we can obtain a weighting matrix

$$K(t_k) = P(t_k | t_n) \left[P(t_k | t_n) + P(t_k | t_k) \right]^{-1} \tag{A.10}$$

The updated estimate at t_k based on data up to and including t_n will now be

$$\hat{x}(t_k | t_n) = K(t_k) \left[\hat{x}(t_k | t_k) - \Phi(t_k, t_n)\, \hat{x}(t_n | t_n) \right] \tag{A.11}$$

and the recursion equation for the updating of the covariance matrix will be

$$P'(t_k | t_n) = \left[I - K(t_k) \right] \Phi(t_k, t_n)\, P(t_n | t_n)\, \Phi^T(t_k, t_n) \tag{A.12}$$

In the present application of the smoothing technique, we are interested in obtaining the best estimate of the orbit at time t_n. Therefore, after each smoothing operation we do not update the orbit at time t_k, but transfer the corrections to time t_n. Then, with the improved orbit we proceed to time t_{k-1} and repeat the smoothing until all points are processed.

Since this type of smoothing process may involve long time arcs and cause numerical difficulties, only the diagonal elements of the covariance matrices are stored during the filtering process. Similarly, only the diagonal elements of the $P(t_n | t_n)$ matrix are used in the transformation. In addition to avoiding numerical difficulties, this approximation saves considerable storage space. However, it must be pointed out that the $P(t_k | t_n)$ matrix is not a diagonal matrix.

C. SYSTEM STANDARD OBSERVATION ERROR

One of the problems in a sequential orbit estimation technique is the estimation of standard deviations of the observations. This is somewhat complicated, as discussed previously in this report, because the standard deviations of the system measurement error include unknown bias errors as well as random errors. A solution to this problem can be obtained by a method of successive approximations in a multiple filtering process.

An approximation of the expected deviations of the measurements from the estimated orbit at a time t_k can be obtained from the diagonal elements of the covariance matrix.

$$R = H(t_k)\, P(t_k)\, H^T(t_k) + Q(t_k) \tag{A.13}$$

which is expressed in terms of the observations.

If ΔS_{ik} is the deviation of the kth measurement from the estimated orbit, then we can write

$$\frac{1.25}{n} \sum_{k=1}^{k=n} \frac{|\Delta S_{ik}|}{(r_{ik})^{1/2}} = C_i \tag{A.14}$$

where n is the number of observations and r_{ik} the diagonal element corresponding to the particular type of observation in matrix R. Both ΔS_{ik} and $(r_{ik})^{1/2}$ include the deviations in the estimated orbit and the measurement. In the case of normal distribution of errors and if the estimate of the standard deviation is correct, then C_i should approach 1 for a sufficiently large number of observations. If $C_i \neq 1$, the discrepancy will be due to the incorrect estimates of the standard deviations in the observations. Therefore, a better approximation can be obtained assuming that the error in the estimate of the orbit is approaching the error in the observations. Under this assumption

$$(q_i)^{1/2}_{\text{improved}} = C_i\, (q_i)^{1/2} \tag{A.15}$$

where $(q_i)^{1/2}$ is the standard deviation of the observation.

This method is used in the triple filtering mode, updating the standard deviations at the end of each filtering. It appears to be working quite well.

D. REJECTION CRITERION

The matrix R discussed in the previous section is composed of two covariance matrices. Matrix HPH^T is computed by the program itself. The matrix Q is an input item for the first filtering. It is a diagonal matrix composed of the variances of the estimated measurement errors In case the errors are not known, they can be estimated by using the triple filtering mode. However, an initial estimate is still required. If the estimate is correct, it is usually standard practice to reject all data that exceed 3-sigma accuracy. However, it is possible that the estimate is low, in which case legitimate observations may be rejected. To avoid this possibility, the following routine is used.

At each observation the quantity n_y is computed:

$$\frac{1.25\,|\Delta S|}{\left(r_y\right)^{1/2}} = n_y \tag{A.16}$$

where ΔS is the difference between the measured and estimated observations, and r_y is the corresponding diagonal element in the R matrix. The n_y's are stored in six boxes according to their values

	N_1	N_2	N_3	N_4	N_5	N_6
$n_y =$	0 - 3	3 - 4	4 - 6	6 - 8	8 - 11	11<

At the end of each filtering phase, the quantities

$$\psi_1 = \frac{N_1}{N}, \ \psi_2 = \frac{N_1 + N_2}{N}, \ \ldots \ \psi_6 = \frac{N_1 + \ldots + N_6}{N} \tag{A.16a}$$

are computed, where $N_1 \ldots N_6$ are the number of observations falling into a particular box. N is the total number of observations.

$$N = N_1 + \ldots + N_6 \tag{A.16b}$$

The ψ_i's are then tested against a number ψ to determine the number of sigmas tolerated.

$$\psi_i < \psi \leq \psi_{i+1} \tag{A.16c}$$

A representative value of $\psi = 0.95$ was established by experiment to give good results. The number of sigmas tolerated in the next filtering phase is found from the following table.

$$\begin{array}{lcccccc} i = & 1 & 2 & 3 & 4 & 5 & 6 \\ \delta = & 3 & 4 & 6 & 8 & 11 & 15 \end{array} \tag{A.16d}$$

E. REVOLUTION NUMBER

Revolution number is defined as the number of nodal crossings of the equator from south to north. An initial revolution number is inputted in the program and the first revolution is added at the first nodal crossing. To save computer time, the nodal crossing is determined from a second order nodal period and finally established by logical tests which are described in the revolution number subroutine.

The time to the first nodal crossing is computed from the input orbital elements as follows.

The true anomaly of the node is

$$\theta_N = 2\pi - \omega \tag{A.17}$$

Then the eccentric anomaly is obtained from

$$\left.\begin{aligned} \operatorname{Cos} E_N &= \frac{\cos\theta_N + e}{1 + e\cos\theta_N} && \text{(A.18a)} \\ \operatorname{Sin} E_N &= \frac{(1 - e^2)^{1/2}\sin\theta_N}{1 + e\cos\theta_N} && \text{(A.18b)} \end{aligned}\right\} 0 \leq E_N \leq 2\pi$$

and the corresponding mean anomaly

$$M_N = E_N - e\sin E_N \tag{A.19}$$

$$\Delta M_N = M_N - M \tag{A.20}$$

where $0 \leq \Delta M \leq 2\pi$

The time to the first nodal crossing is

$$t_N = \frac{\Delta M}{\left(\frac{\mu}{a^3}\right)^{1/2}} \tag{A.21}$$

To determine the revolution number at any arbitrary time, T_{pr}, we obtain

$$m_0 = \frac{T_{pr} - T_{in} - t_N}{P_N} \tag{A.22}$$

where T_{in} is the initial time and P_N is the approximate nodal period

$$P_N = \frac{2\pi}{n}\left\{1 - \frac{3}{2} J_2 \frac{R_E^2}{C^2}\left[3 - \frac{e^2}{2} - \sin^2 i\left(4 - \frac{3}{4} e^2\right)\right]\right\} \tag{A. 23}$$

The following values then are used in the logical tests (see subroutine PROUT).

$$m = m_0 + 1 \tag{A. 23a}$$

$$|m_1| = \text{absolute value of fraction of } m \tag{A. 23b}$$

$$\pm m_2 = \text{integer of } m \tag{A. 23c}$$

$$\pm m_3 = \text{integer of } m_0 \tag{A. 23d}$$

F. CONVERSION FROM POSITION AND VELOCITY VECTORS TO ORBITAL ELEMENTS

Given are the components of the position and velocity vectors x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$, and the constant μ.

Components in an orbital axes system ($y_\omega = 0$, $z_\omega = 0$) are

$$x_\omega = (x^2 + y^2 + z^2)^{1/2} \tag{A. 24}$$

$$V^2 \equiv V_\omega^2 = \dot{x}^2 + \dot{y}^2 + \dot{z}^2 \tag{A. 25}$$

$$\dot{x}_\omega = \frac{x\dot{x} + y\dot{y} + z\dot{z}}{x_\omega} \tag{A. 26}$$

$$\dot{y}_\omega = \left(V_\omega^2 - \dot{x}_\omega^2\right)^{1/2} \tag{A. 27}$$

The planar orbital elements associated with the equations of conic sections in Cartesian form (see Appendix of Ref. 1) are

$$A = 1 - \frac{x_\omega \dot{y}_\omega^2}{\mu} \tag{A-28}$$

$$B = \frac{x_\omega \dot{x}_\omega \dot{y}_\omega}{\mu} \tag{A-29}$$

$$C = \frac{(x_\omega \dot{y}_\omega)^2}{\mu} \tag{A. 30}$$

and eccentricity

$$e = (A^2 + B^2)^{1/2} \tag{A.31}$$

Semimajor axis is obtained from

$$a = \frac{C}{1 - e^2} \tag{A.32}$$

To obtain the remaining elements, we compute the direction cosines of the x_ω axis

$$\xi_1 = \frac{x}{x_\omega}, \quad \eta_1 = \frac{y}{x_\omega}, \quad \zeta_1 = \frac{z}{x_\omega} \tag{A.33}$$

The direction cosines of the z_ω axis are obtained by taking the vector product of the position and velocity vectors

$$\xi_3' = y\,\dot{z} - z\,\dot{y}, \quad \eta_3' = z\,\dot{x} - x\,\dot{z}, \quad \zeta_3' = x\,\dot{y} - y\,\dot{x} \tag{A.34}$$

$$d = \left(\xi_3'^{\,2} + \eta_3'^{\,2} + \zeta_3'^{\,2}\right)^{1/2} \tag{A.35}$$

$$\xi_3 = \frac{\xi_3'}{d}, \quad \eta_3 = \frac{\eta_3'}{d}, \quad \zeta_3 = \frac{\zeta_3'}{d} \tag{A.36}$$

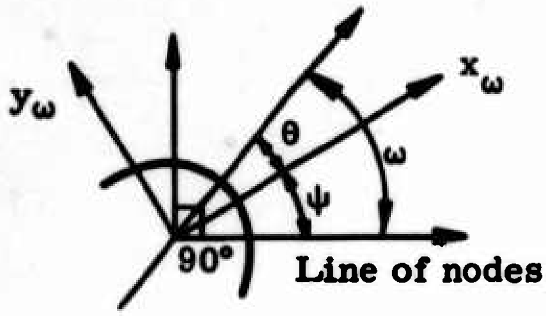
Consequently, the inclination is given by

$$\left.\begin{aligned} \sin i &= \left(1 - \zeta_3^2\right)^{1/2} \\ \cos i &= \zeta_3 \end{aligned}\right\} \quad 0 \leq i \leq \pi \tag{A.37}$$

The right ascension of the ascending node is obtained from the vector product of the normal to the orbital plane (z_ω axis) and the normal to the reference plane (z axis), which gives

$$\left.\begin{aligned} \sin \Omega &= \eta_N = \frac{\xi_3}{\left(\xi_3^2 + \eta_3^2\right)^{1/2}} \\ \cos \Omega &= \xi_N = \frac{-\eta_3}{\left(\xi_3^2 + \eta_3^2\right)^{1/2}} \end{aligned}\right\} \quad 0 \leq \Omega \leq 2\pi \tag{A.38}$$

The angle ψ is obtained by taking first the scalar product of the x_ω axis and the line of nodes, and then the x_ω axis and an axis in the orbital plane normal to the line of nodes



$$\left.\begin{aligned} \cos\psi &= \xi_1 \xi_N + \eta_1 \eta_N \\ \sin\psi &= \zeta_3 (\eta_1 \xi_N - \xi_1 \eta_N) + \zeta_1 (\xi_3 \eta_N - \eta_3 \xi_N) \\ & 0 \leq \psi \leq 2\pi \end{aligned}\right\} \qquad \text{(A. 39)}$$

The angle θ is obtained from the relationship

$$\left.\begin{aligned} \sin\theta &= -\frac{B}{e} \\ \cos\theta &= -\frac{A}{e} \end{aligned}\right\} \quad 0 \leq \theta \leq 2\pi \qquad \text{(A. 40)}$$

It is measured from the x_ω axis-positive counterclockwise. Then the argument of perigee is simply

$$\omega = \psi + \theta \qquad 0 \leq \omega \leq 2\pi \qquad \text{(A. 41)}$$

The eccentric anomaly is obtained from the familiar relationships

$$\left.\begin{aligned} \cos E &= \frac{\cos\theta + e}{1 + e\cos\theta} \\ \sin E &= \frac{-(1 - e^2)^{1/2} \sin\theta}{1 + e\cos\theta} \end{aligned}\right\} \quad 0 \leq E_0 \leq 2\pi \qquad \text{(A. 42)}$$

From which

$$M = E - e\sin E \qquad \text{(A. 43)}$$

It must be remembered that the x_ω, y_ω, z_ω axes system is considered here as an inertial axes system with the x_ω axis pointing at the satellite at the particular instant of time.

G. CONVERSION TO POSITION AND VELOCITY COORDINATES

First, we find the transformation equations from the reference axes system x, y, z to the orbital axes system $\bar{X}$, $\bar{Y}$, $\bar{Z}$. The reference axes system will, normally, be the equatorial axes system with x axis toward the vernal equinox, z axis pointing north and y axis in the equatorial plane completing a right hand system.

Starting with the reference system we rotate about z axis through the angle Ω.

$$x_1 = \cos\Omega x + \sin\Omega y \tag{A. 44a}$$

$$y_1 = -\sin\Omega x + \cos\Omega y \tag{A. 44b}$$

$$z_1 = z \tag{A. 44c}$$

Next the system is rotated about the new x_1 axis through the angle i

$$x_2 = x_1 \tag{A. 45a}$$

$$y_2 = \cos i\, y_1 + \sin i\, z_1 \tag{A. 45b}$$

$$z_2 = -\sin i\, y_1 + \cos i\, z_1 \tag{A. 45c}$$

Finally, we rotate the system about the z_2 axis through the angle ω

$$\bar{X} = \cos\omega\, x_2 + \sin\omega\, y_2 \tag{A. 46a}$$

$$\bar{Y} = -\sin\omega\, x_2 + \cos\omega\, y_2 \tag{A. 46b}$$

$$\bar{Z} = z_2 \tag{A. 46c}$$

The operation can be written in matrix form

$$\begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} \quad \begin{bmatrix} \cos\omega & \sin\omega & 0 \\ -\sin\omega & \cos\omega & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos i & \sin i \\ 0 & -\sin i & \cos i \end{bmatrix} \begin{bmatrix} \cos\Omega & \sin\Omega & 0 \\ -\sin\Omega & \cos\Omega & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{A. 47}$$

Performing the matrix multiplication we obtain

$$\begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} = \begin{bmatrix} P_x & P_y & P_z \\ Q_x & Q_y & Q_z \\ R_x & R_y & R_z \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{A. 48}$$

where

$$P_x = \cos\omega \cos\Omega - \sin\omega \sin\Omega \cos i$$

$$P_y = \cos\omega \sin\Omega + \sin\omega \cos\Omega \cos i$$

$$P_z = \sin\omega \sin i$$

$$Q_x = -\sin\omega \cos\Omega - \cos\omega \sin\Omega \cos i$$

$$Q_y = -\sin\omega \sin\Omega + \cos\omega \cos\Omega \cos i$$

$$Q_z = \cos\omega \sin i$$

$$R_x = \sin\Omega \sin i$$

$$R_y = -\cos\Omega \sin i$$

$$R_z = \cos i$$

Since this is an orthogonal transformation

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} P_x & Q_x & R_x \\ P_y & Q_y & R_y \\ P_z & Q_z & R_z \end{bmatrix} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} \tag{A. 49}$$

Next we transform to an axes system where the new x_ω axis is in the direction of the satellite at time t.

This means a rotation about $\bar{Z}$ axis through the angle θ giving the transformation equations

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} P_x & Q_x & R_x \\ P_y & Q_y & R_y \\ P_z & Q_z & R_z \end{bmatrix} \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_\omega \\ y_\omega \\ z_\omega \end{bmatrix} \qquad \text{(A.50)}$$

Since

$$A = -e\cos\theta$$

$$B = -e\sin\theta$$

$$C = a(1-e^2)$$

we obtain, in conjunction with Eqs (A.12), (A.13) and (A.14) of Ref. 1,

$$x_\omega = \frac{a(1-e^2)}{1+e\cos\theta} \qquad \text{(A.51a)}$$

$$y_\omega = 0 \qquad \text{(A.51b)}$$

$$\dot{x}_\omega = -e\sin\theta\left[\frac{\mu}{a(1-e^2)}\right]^{1/2} \qquad \text{(A.51c)}$$

$$\dot{y}_\omega = (1+e\cos\theta)\left[\frac{\mu}{a(1-e^2)}\right]^{1/2} \qquad \text{(A.51d)}$$

$$z_\omega = \dot{z}_\omega = 0 \qquad \text{(A.51e)}$$

Introducing the velocity coordinates and multiplying the last column vector by the matrix in Eqs (A.50), we obtain a column matrix

$$\begin{bmatrix} \overline{X} \\ \overline{Y} \\ \overline{Z} \\ \dot{\overline{X}} \\ \dot{\overline{Y}} \\ \dot{\overline{Z}} \end{bmatrix} = \begin{bmatrix} \dfrac{a(1-e^2)\cos\theta}{1+e\cos\theta} \\ -\dfrac{a(1-e^2)\sin\theta}{1+e\cos\theta} \\ 0 \\ \sin\theta\left[\dfrac{\mu}{a(1-e^2)}\right]^{1/2} \\ (e+\cos\theta)\left[\dfrac{\mu}{a(1-e^2)}\right]^{1/2} \\ 0 \end{bmatrix} \qquad \text{(A.52)}$$

To introduce the eccentric anomaly, we use the relationships

$$\cos \theta = \frac{\cos E - e}{1 - e \cos E} \tag{A.53a}$$

$$\sin \theta = \frac{- (1 - e^2)^{1/2} \sin E}{1 - e \cos E} \tag{A.53b}$$

which give

$$\begin{bmatrix} a(\cos E - e) \\ a(1 - e^2)^{1/2} \sin E \\ 0 \\ - \dfrac{\sin E}{1 - e \cos E} \left(\dfrac{\mu}{a}\right)^{1/2} \\ \dfrac{\cos E_0}{1 - e \cos E} (1 - e^2)^{1/2} \left(\dfrac{\mu}{a}\right)^{1/2} \\ 0 \end{bmatrix} = \begin{bmatrix} \bar{X} \\ \bar{Y} \\ 0 \\ \dot{\bar{X}} \\ \dot{\bar{Y}} \\ 0 \end{bmatrix} \tag{A-54}$$

The transformation equations in matrix form can now be written

$$\begin{bmatrix} x \\ y \\ z \\ \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix} = \begin{bmatrix} P_x & Q_x & R_x & 0 & 0 & 0 \\ P_y & Q_y & R_y & 0 & 0 & 0 \\ P_z & Q_z & R_z & 0 & 0 & 0 \\ 0 & 0 & 0 & P_x & Q_x & R_x \\ 0 & 0 & 0 & P_y & Q_y & R_y \\ 0 & 0 & 0 & P_z & Q_z & R_z \end{bmatrix} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ 0 \\ \dot{\bar{X}} \\ \dot{\bar{Y}} \\ 0 \end{bmatrix} \tag{A.55}$$

which can be simplified to the following form

$$\begin{bmatrix} x & \dot{x} \\ y & \dot{y} \\ z & \dot{z} \end{bmatrix} = \begin{bmatrix} P_x & Q_x \\ P_y & Q_y \\ P_z & Q_z \end{bmatrix} \begin{bmatrix} \bar{X} & \dot{\bar{X}} \\ \bar{Y} & \dot{\bar{Y}} \end{bmatrix} \tag{A.56}$$

The advantage of forms (A. 55) and (A. 56) is that the elements which determine the Keplerian orbit a, e, E and the elements which determine the orientation of the orbit Ω, i, ω are completely separated.

H. COMPUTATION OF EPHEMERIS

In one part of the ephemeris computations, we determine the satellite longitude, geocentric and geodetic latitude and altitude above the reference ellipsoid from the position and velocity vector at a given time.

The geocentric latitude is simply

$$\phi = \arctan \left[\frac{z}{\left(r^2 - z^2\right)^{1/2}} \right] \tag{A.57}$$

where

$$r = \left(x^2 + y^2 + z^2\right)^{1/2}$$

The approximate satellite altitude above the ellipsoid is then

$$H = r - R_E \left(\frac{1 + \tan^2 \phi}{1 + \frac{\tan^2 \phi}{f_E}} \right)^{1/2} \tag{A.58}$$

where R_E is the Earth's mean equatorial radius and

$$f_E = (1 - f)^2 \tag{A.59}$$

where f is the flattening.

The geodetic latitude is obtained by a successive approximation technique which is most suitable for an electronic computer. Computing a value

$$C = \left[\frac{1 + \tan^2 \Phi}{1 + f_E \tan^2 \Phi} \right]^{1/2} \qquad \text{(A. 60)}$$

we substitute $\tan \phi$ for $\tan \Phi$ for the first iteration. Then the geodetic latitude is

$$\Phi = \arctan \left[\frac{h + C}{h + f_E C} \tan \phi \right] \qquad \text{(A. 61)}$$

where

$$h = \frac{H}{R_E}$$

An improved C is then computed using $\tan \Phi$ in Eq (A. 60) and the process repeated to the desired accuracy. Convergence usually occurs in one or two iterations.

Satellite longitude is determined as follows. The right ascension of the satellite is

$$\lambda_S = \arctan \left(\frac{y}{x} \right) \qquad \text{(A. 62)}$$

The right ascension of the Greenwich meridian is

$$\lambda_G = 1.746647719 + 6.30038809863056\, d + 0.5064 \times 10^{-14}\, d^2 + \Delta\lambda \qquad \text{(A. 63)}$$

where d are Julian days from the epoch 1950 January 1, 0^h UT (see Ref. 1, III-D). The satellite longitude is then

$$\lambda = \lambda_G - \lambda_S \qquad \text{(A. 64)}$$

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13. ABSTRACT

This program is based on the analytical work contained in a previous Report AFCRL 65-579 (Martin Report ER 13950, Ref. 1). In addition, some analytical methods not covered in the above report are presented in the appendix of this report. (AD-625 453)

The operating modes, general features and accuracy of the program are discussed. Operating instructions and input/output descriptions and definitions are provided. All symbols used in the program are listed and defined. Flow charts, descriptions and explanations of the program and subroutines are also included.

The program is written in Fortran IV and machine language (MAP). Double precision is used extensively.

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